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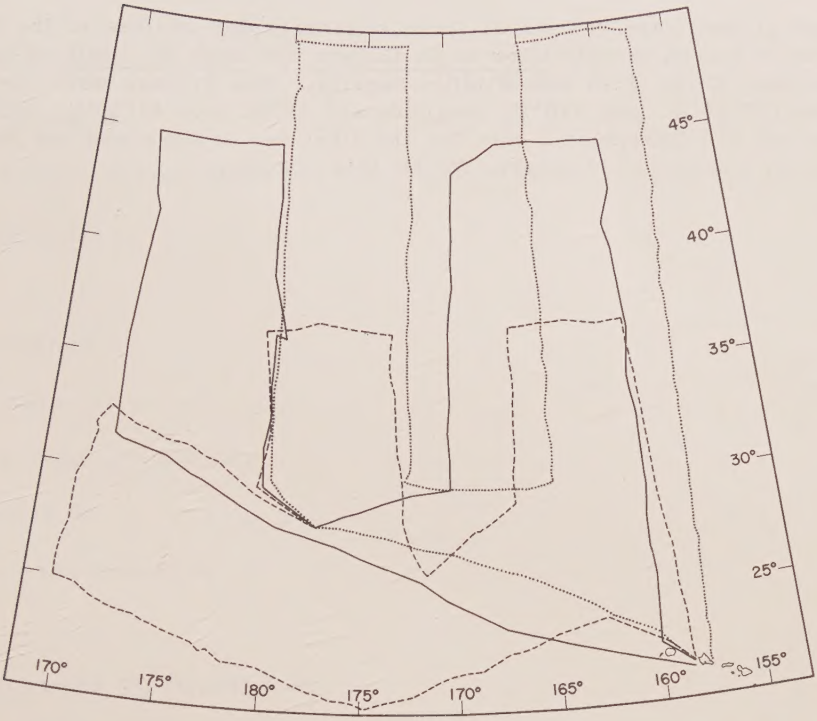

OCEANOGRAPHIC OBSERVATIONS IN THE CENTRAL NORTH PACIFIC, SEPTEMBER 1954 - AUGUST 1955

By

James W. McGary, Oceanographer, and Edward D. Stroup
Pacific Oceanic Fishery Investigations
Honolulu, T. H.
Bureau of Commercial Fisheries

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ABSTRACT

This report presents the results of three oceanographic cruises to the temperate central North Pacific by the research vessels Charles H. Gilbert and Hugh M. Smith of the Pacific Oceanic Fishery Investigations, U. S. Fish and Wildlife Service. The cruises were confined to the area bounded roughly by 157°30'W. and 170°E. longitude and 20°N. and 49°30'N. latitude. The report includes the observed and interpolated data for the first two cruises and the plots of the various field, such as salinity and dissolved oxygen, for all three cruises.

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OCEANOGRAPHIC OBSERVATIONS IN THE CENTRAL NORTH PACIFIC, SEPTEMBER 1954 - AUGUST 1955

By

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Bureau of Commercial Fisheries

This report is the fourth in a series of oceanographic data reports by the Pacific Oceanic Fishery Investigations (POFI) on the waters to the north and northeast of the Hawaiian Islands. It contains physical and chemical data collected on three oceanographic cruises between September 1954 and August 1955. The surveys covered by this and the previous reports were made as part of the albacore, Germo alalunga, investigations which are being supported by funds made available by the Saltonstall-Kennedy Act. The first two reports (McGary and Stroup 1956; McGary, Jones, and Austin, 1956) embody only data collected on individual oceanographic cruises during the winter of 1954 and summer of 1955; the third report (Callaway 1957) contains oceanographic data collected on three exploratory fishing cruises during the summer and fall of 1956. The manner and detail of the presentation in this report are somewhat different from those of the first two of the series. The text does not contain the detailed discussion and partial analysis of the data that was included in the first report (McGary and Stroup 1956), but like the second (McGary, Jones, and Austin, 1956) it merely contains a discussion of the methods and a resumé of the results. In common with the first report, however, it contains plots of the lateral and vertical fields of the various parameters in addition to the tabulated data. The biological data taken on these cruises and the limited physical data taken on fishing cruises in conjunction with the oceanographic cruises have been published elsewhere, as cited in this report.

The first survey, Charles H. Gilbert cruise 17, during the period September 17 to November 7, 1954, was confined to the area between 21°N. and 45°N. latitude, 160°W. to 170°E. longitude. An exploratory-fishing cruise, John R. Manning cruise 22, was made concurrent with this survey, and the data have been analyzed and published by Shomura and Otsu (1956). The second survey, Hugh M. Smith cruise 27, during the period January 5 to February 21, 1955, covered the area bounded by 20°N. and 39°N. latitude between 160°W. and 170°E. longitude. The latter part of John R. Manning cruise 23, an exploratory fishing cruise, was made concurrent with this survey; the resulting data are included in the report by Shomura and Otsu (1956). The third survey, Hugh M. Smith cruise 30, was made during the period July 15 to August 28, 1955, in the area between the Hawaiian Islands and 49°30'N., from 157°30'W. to 180°. This cruise was a part of Operation NORPAC, a quasi-synoptic oceanographic and biological survey of the Pacific north of 20°N., including a portion of the Bering Sea, undertaken jointly by research agencies of Canada, Japan, and the United States. The tabulated data and temperature cross sections have already been published (McGary, Jones, and Austin, 1956), and much of the resulting data will also be incorporated in an atlas which is to be published jointly by Scripps Institution of Oceanography and the Japanese Hydrographic Office.

CHARLES H. GILBERT CRUISE 17

Itinerary

The Gilbert departed from Pearl Harbor on September 17, 1954. The vessel stopped at Midway Islands on October 11-14, 1954, for fuel, stores, and to exchange personnel. A brief stop was made at Laysan Island on November 3 to inspect the wildfowl refuge and to make a bait-fish survey of the reefs. The vessel returned to Pearl Harbor on November 7, 1954. The cruise track and station positions are shown in figure 1.

Primary Missions

1. Forty oceanographic stations were occupied at the positions indicated in figure 1. Twenty-five scheduled stations were omitted because of high winds and rough seas.

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Casts with 13 Nansen bottles were made at all stations. The bottle intervals in the upper 200 meters were determined from the vertical temperature structure as indicated by the bathythermogram taken at the station. Below 200 meters they were placed at standard depths (U. S. Navy Hydrographic Office, 1955). All bottles carried two reversing thermometers; bottles 5, 7, 9, 11, and 13 carried one protected and one unprotected thermometer; all others carried two protected thermometers.

At the first 8 stations the casts were made to 1,200 meters, but after station 8 they were made to only 1,000 meters. This change in depth was necessary because of the loss of a portion of the wire cable.

At station 34 (35°45'N., 171°32'E.) the bottom three bottles of the cast (600, 800, and 1,000 m.) fouled a ridge or pinnacle. The position was on a bearing of 340°T. and a distance of 30 miles from a sea mount shown on the chart (H. O. 0528). Possibly an uncharted ridge extending out from this sea mount was fouled. Unfortunately all of the echo sounding equipment was inoperative so bottom profiles could not be obtained. A few, small, pelecypod shells and bits of well-aged coral were brought up in the thermometer frame of the 800-meter bottle.

2. Salinity samples were drawn from each Nansen bottle and returned to the POFI laboratory for analysis. Additional surface samples were taken at every third BT on the run from station 40 to Pearl Harbor. To prevent evaporation during storage, each sample was stoppered with a paraffin-impregnated cork in addition to the ordinary screw cap. The salinities of the station samples are given in the station data (table 1) and the surface salinities at the BT's are given in the last column of the BT data (table 2). The salinity profiles are shown in figures 28 to 30, the surface salinity in figure 31, and the salinity on the 25.2, 26.0, and 26.8 sigma-t surfaces in figures 32 to 34.

3. Dissolved oxygen analyses by the Winkler method were made aboard ship on samples from each depth at all oceanographic stations. The results are given in table 1. The profiles along 160°W., 170°W., and 180° longitudes are shown in figures 35 to 37. The distributions on the 25.2, 26.0, and 26.8 sigma-t surfaces are shown in figures 38 to 40.

4. Inorganic-phosphate analyses were also made aboard ship by the molybdenum-blue method (Wooster and Rakestraw 1951). Analyses were made on samples from all depths at all stations except 19 through 26. Photometer (Lumetron) failure, which could not be repaired until parts were obtained at Midway, prevented analyses at these stations. The observed values are given in table 1 and the profiles in figures 41 to 43. Adequate charts of the surface distribution and on surfaces of constant sigma-t could not be drawn because of missing data resulting from instrument failure and the omission of stations in rough weather.

5. Bathythermograph lowerings were made at all oceanographic stations and at 30-mile intervals between stations. On the run along the islands of the Hawaiian Archipelago between station 40 and Pearl Harbor the interval was shortened to 2-1/2 hours or approximately 20 miles to obtain a more detailed profile. The observations (Log Sheet B) made at the BT lowerings are summarized in table 2. Figures 13 to 20 are the surface temperature distribution and profiles drawn from the BT data.

6. Throughout the cruise a continuous record of the surface temperature was made with a recording thermograph.

7. When weather conditions permitted, Secchi disc observations (total of 12) of transparency and water color according to the Forel scale were made at all daylight oceanographic stations. These observations are recorded in the station data headings (table 1).

Secondary Missions

1. Oblique 0-100 m. zooplankton hauls of 30 minutes' duration with a 1-meter net of 30XXX silk grit gauze were made at each station. These data will be summarized in a separate report.[2]

2. From two to six lines were trolled during all daylight runs. The results have been summarized by Shomura and Otsu (1956).

---

[2] "Zooplankton distribution and biological indicators related to oceanographic conditions and to albacore abundance in the central North Pacific," manuscript being prepared by E. C. Jones of Pacific Oceanic Fishery Investigations.

3. The wheel watch maintained a record of all tuna schools, bird flocks, and scattered birds and mammals sighted.

4. Synoptic weather observations, made daily at 0000, 0600, 1200, and 1800 GCT, are summarized in table 3. In addition, certain standard weather observations accompanied all BT lowerings.

   Seven storms with winds of moderate gale force (28 knots) or greater were encountered. They varied in duration from less than 6 hours to over 72 hours. The most violent occurred on October 25 at approximately 45°N., 172°E., when the barometer dropped to 986.5 mb. and the winds reached a velocity of 68 knots. The storm tracks during the months of the cruise are shown in figures 44 to 46.

5. The EDO depth sounder failed completely on September 30, so bottom profiles were obtained of only the southern part of the section along 160°W. longitude. While the instrument was functioning, some excellent recordings were made of the evening rise of the deep-scattering layers to the surface.

6. On November 3, 1954, about 6 hours were spent ashore on Laysan Island, which is a part of the Hawaiian National Wildlife Refuge. Only a few scattered Laysan albatross and small numbers of blackfooted albatross, Laysan finch, shearwater, terns, and one flock of about 50 young frigate birds were sighted on the island. There were no signs of nesting at this time. The Hawaiian monk seal population was estimated to be between 100 and 150.

Form and Location of Field Data

The following records were kept on Charles H. Gilbert cruise 17; they are on file at POFI except as otherwise noted:

Original oceanographic data, Log Sheet "A"
Bathythermograph Log Sheet "B" (duplicates at Scripps Institution of Oceanography)
Chemical data sheets
BT slides (Scripps Institution of Oceanography)
Thermograph records
Track charts
Deck log
Occurrence of tuna schools, birds, and aquatic mammals
Plankton log
Flowmeter and sampler calibration log
Standardized surface trolling data sheets
Scientists' log
USWB Form 1210F (original at U. S. Weather Bureau Records Center, Asheville, N. C.)
EDO depth recorder charts
Barograph records
Tuna morphometric sheets - short form

HUGH M. SMITH CRUISE 27

Itinerary

The Smith departed from Pearl Harbor on January 5, 1955. Engine trouble developed on January 19 at 32°30'N., 170°30'E. The vessel put into Midway Islands for repairs, arriving on January 24 and departing Midway on January 31. About 12 hours were spent on February 10 surveying the wildfowl refuge at Laysan Island. The vessel returned to Pearl Harbor on February 21, 1955. The cruise track and station positions are shown in figure 47.

Primary Missions

1. Forty-nine oceanographic stations were occupied at the positions indicated on figure 47. Casts with 13 bottles were made on all stations to approximately 1,200 m. The bottle intervals in the upper 200 meters were determined from the vertical temperature structure indicated by the bathythermogram taken at the station. Each bottle carried two protected reversing thermometers and bottles 5, 7, 9, 11, and 13 also carried an unprotected thermometer.

2. Salinity samples were drawn from each Nansen bottle and returned to the POFI laboratory for analysis. In addition, at every second BT between 32°30'N., 170°30'E. and Midway Islands, surface samples were taken. The salinity of the station samples is given in the station data (table 4) and at the BT's in the last column of the BT data, table 5. The salinity profiles are presented in figures 78 to 82 and the distribution at the surface and on the 25.2, 26.0, and 26.8 sigma-t surfaces in figures 83 to 86.

3. Dissolved oxygen analyses using the Winkler method were made aboard ship on samples from each depth. The observed values are given in table 4, the profiles in figures 87 to 91, and the distribution on the 25.2, 26.0, and 26.8 sigma-t surfaces in figures 92 to 94.

4. Inorganic phosphate analyses were also made aboard ship on samples from each depth at all stations. Additional surface samples

were collected and analyzed on the run between 32°30'N., 170°30'E. and Midway Islands. The results are tabulated in the station data, table 4, and BT log sheet summaries, table 5. The profiles are given in figures 95 to 99 and the surface distribution in figure 100. Only the plots on the 26.0 and 26.8 sigma-t surfaces were plotted (figs. 101 and 102), since the range on the 25.2 sigma-t surface was only from 0.19 to 0.40 µg at./L.

5. Bathythermograph lowerings were made at each oceanographic station and at approximately 30-mile intervals between stations. The observations (Log Sheet "B") are summarized in table 5; figures 63 to 68 show the temperature profiles and surface temperature distribution drawn from the BT data.

6. A continuous record of the surface water temperature was made by means of a recording thermograph.

7. A 30-minute, 0-100 m. oblique plankton haul with a 1-meter net of 30XXX silk grit gauze was made at each oceanographic station except at station 14. This haul was omitted because of rough seas. The plankton data will be summarized in another report (Jones MS.).

8. Twenty-six collections were made with 6- and 10-foot Isaacs-Kidd mid-water trawls. An analysis of these collections will be presented in a separate report.

9. Night-light collections were attempted at oceanographic stations 61 and 66. At station 61 only 12 sauries were taken and at station 66 there was no catch.

Secondary Missions

1. Five lines were trolled during daylight hours. The results have been summarized by Shomura and Otsu (1956).

2. The wheel watch maintained a record of all tuna schools, bird flocks, and scattered birds and mammals sighted.

3. Synoptic weather observations were made daily at 0000, 0600, 1200, and 1800 GCT; the resulting data are summarized in table 6. In addition, certain standard weather observations accompanied all BT lowerings. The anemometer failed on February 8, 1955, and the winds recorded after 1640 GCT on that date were estimated. Five storms with winds of moderate gale force (28 knots) or greater were encountered. They varied in duration from 4 to 21 hours. The storm tracks during the months of the cruise are shown in figures 103 and 104.

4. A bait-fish survey was conducted on Midway and Laysan Islands. The results will be summarized in a separate report.

5. A bird count was conducted on Laysan Island with emphasis on the rare Laysan Duck. These data will also be covered in a separate report.

6. A count was made of the Hawaiian monk seals on Midway Islands and on Laysan Island. A total of 26 seals were counted on Midway Islands. On Laysan Island there were 105, consisting of 67 adults (200 lbs. or over), 19 juveniles (50-200 lbs.) and 19 pups (about 25 lbs.). One of the pups was born on the day the survey was made (February 10, 1955).

Form and Location of Field Data

The following records were kept on Hugh M. Smith cruise 27; they are on file at POFI except as otherwise noted:

Barograph records
Bathythermograph Log Sheet "B" (duplicates at Scripps Institution of Oceanography)
Bathythermograph slides (Scripps Institution of Oceanography)
Chemical data sheets
Deck log
Flowmeter and sampler calibration log
Light fishing station log
Occurrence of tuna schools, birds, and aquatic mammals
Original oceanographic data, Log Sheet "A"
Plankton log
Scientists' log
Tuna morphometric sheets - short form
Standardized surface trolling data sheets
Thermograph records
Thermometer arrangement forms
Track charts
Trawling log
USWB Form 1210F (original at U. S. Weather Bureau Records Center, Asheville, N. C.)

HUGH M. SMITH CRUISE 30

The description of the cruise, methods, and the observed data have already been published (McGary, Jones, and Austin 1956). Only the processed data, consisting largely of profiles and distribution of the various fields at the sea surface and on surfaces of constant thermosteric anomaly, are included in this report (figs. 105 through 144).

LABORATORY METHODS AND TECHNIQUES

Most of the methods used in the chemical analyses and in preparing the graphs of the distribution of the various fields have been described in previous reports (Cromwell 1951, Stroup 1954, McGary and Stroup 1956, McGary, Jones, and Austin 1956, King et al. 1957). Only the procedures that varied to some degree from those of previous reports will be discussed.

The salinity determinations were made by a new modification of Fajan's adsorption indicator method developed by Van Landingham (1957) and adapted to Knudsen's techniques for sea water. It gives a much sharper end point than the potassium chromate indicator and permits a routine precision of about 0.03 percent.

The relative density profiles and surfaces for Charles H. Gilbert cruise 17 (figs. 21-24) and Hugh M. Smith cruise 27 (figs. 74-77) are expressed in the terms of sigma-t (LaFond 1951). Following the suggestion of Montgomery and Wooster (1954), the use of sigma-t was replaced with the thermosteric anomaly (δ_t) in the plots of Hugh M. Smith cruise 30 (figs. 120-122). The latter consists of the salinity and temperature terms of the anomaly of specific volume, i. e.

$$\delta_t = \delta_s + \delta_t + \delta_{st}$$

Montgomery and Wooster defined thermosteric anomaly as "the anomaly of specific volume (steric anomaly) that would be attained if the water were changed isothermally to a standard pressure of one atmosphere" and assigned the dimensions centiliters per ton (cl./ton). The advantage of the thermosteric anomaly is that, if extreme precision is not desired, it can be used for graphical hydrostatic computations for the upper 500-1,000 m. Montgomery and Wooster found that, in the equatorial Pacific, the range of the pressure terms amounted to only 6 cl./ton, which is 3 cm. in thickness for a 500-db. layer.

Two different methods were also employed in making the hydrostatic calculations. Those for Charles H. Gilbert cruise 17 (figs. 2-4 and 8-12) and for Hugh M. Smith 27 (figs. 48-52 and 58-62) were calculated from the equations developed by Ekman in the manner described by LaFond (1951), whereas those for Hugh M. Smith cruise 30 (figs. 106-109 and 114-118) were computed by a graphical method developed by Klein (MS.).[3]

The zonal (east-west) components of the geostrophic currents were computed and contoured for all three cruises (figs. 5-7, 53-57, and 110-113). This was done to permit future calculations of the volume transport through the upper 1,000 m. of each section. The currents were computed by the formulae derived by Sandstrom and Helland-Hansen (LaFond 1951, p. 17, and Cromwell 1951). Briefly, the procedure was to compute the mean current for each degree of latitude at each depth by using the dynamic heights from the isobaric surface profiles. The values were then plotted at the mid-point of each degree of latitude and at the proper depth. The velocity field was then contoured assuming that the computed values represented the velocity at each point.

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[3] "A new method for processing oceanographic data," unpublished manuscript by Hans Klein, Scripps Institution of Oceanography.

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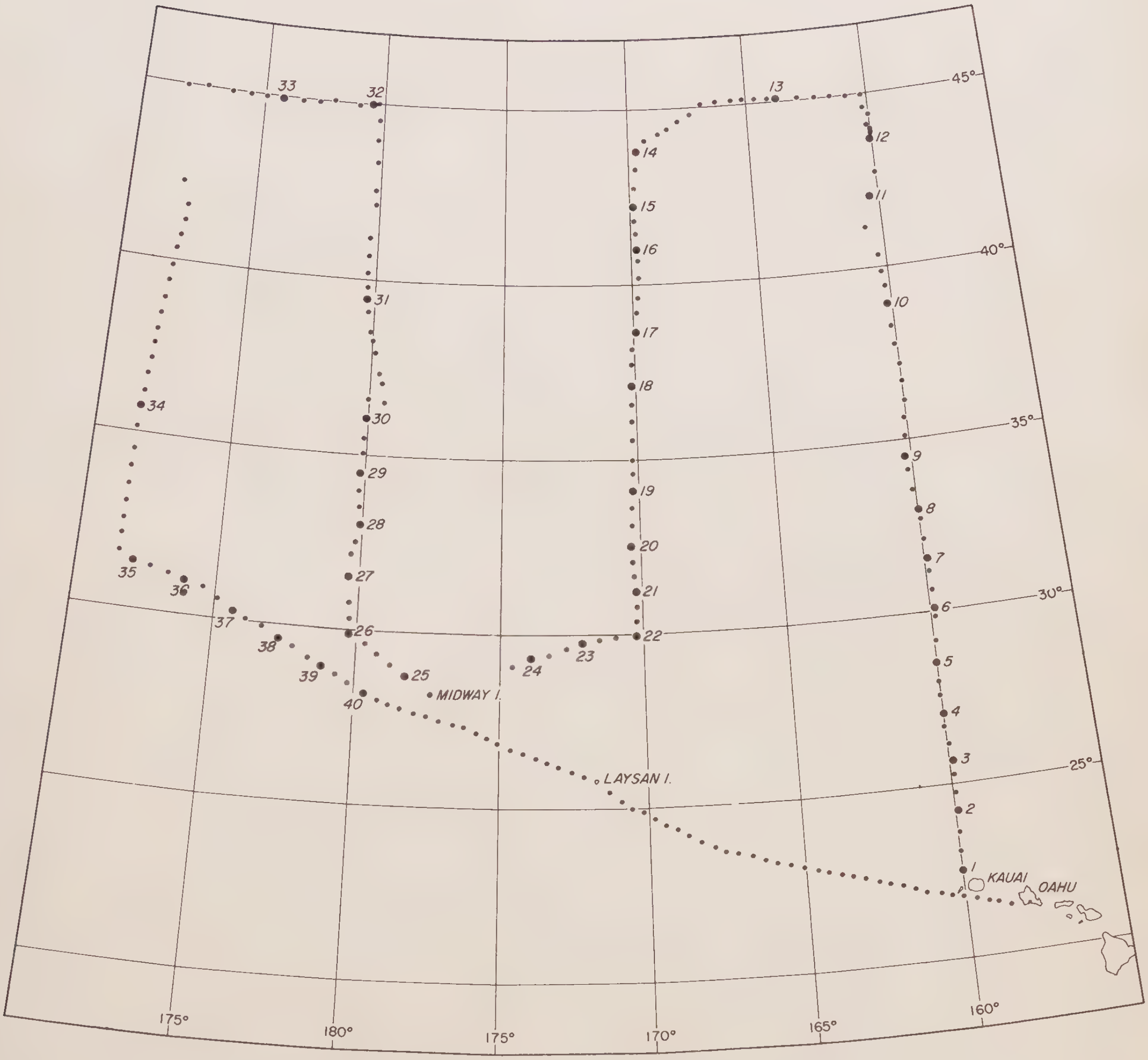
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LAYSAN I.
KAUAI
OAHU

Figure 1.--Oceanographic station positions, *Charles H. Gilbert* cruise 17, September-November 1954. Large numbered dots indicate oceanographic stations; small dots indicate positions of BT lowerings between stations.

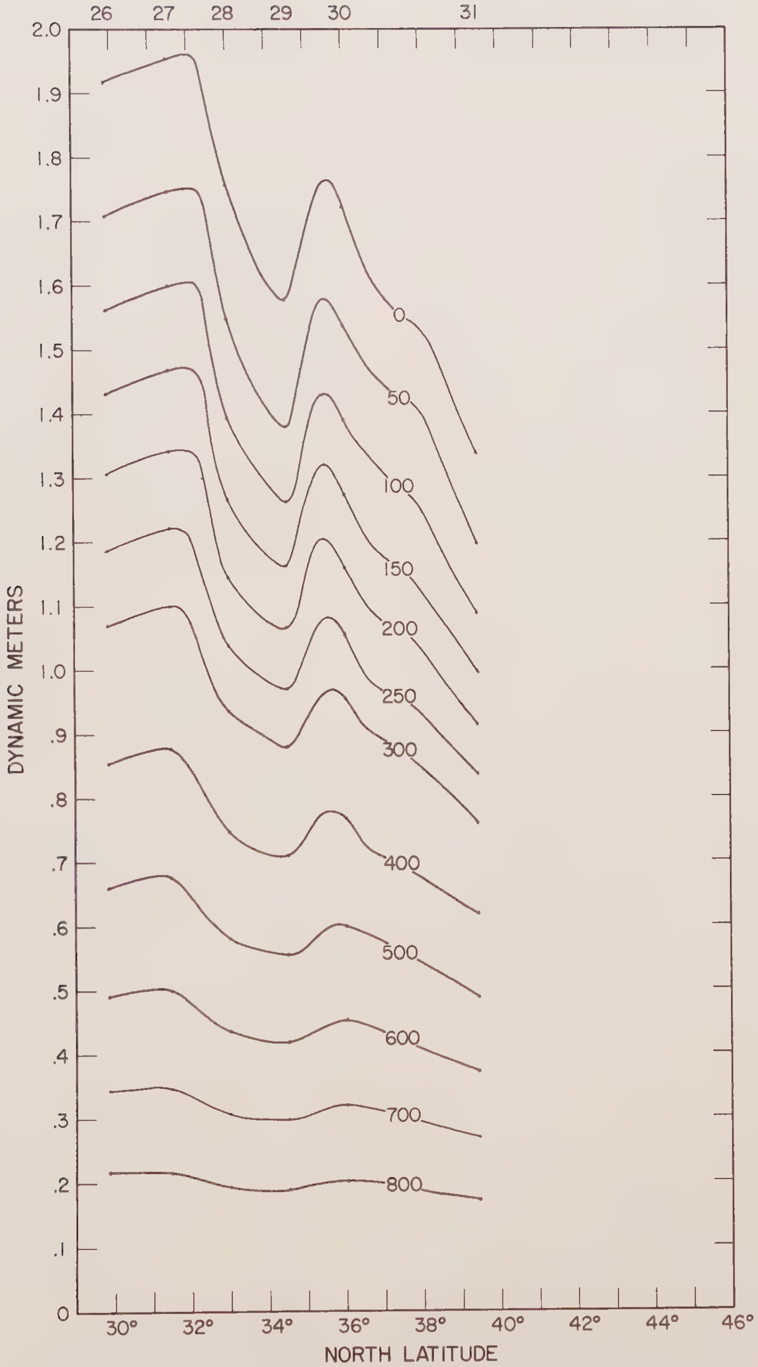


Figure 2.--Smoothed geopotential anomaly of the isobaric surfaces relative to the 1,000-db. surface along the 180th meridian; Charles H. Gilbert cruise 17, stations 26-31, September-November 1954. Points represent computed values.

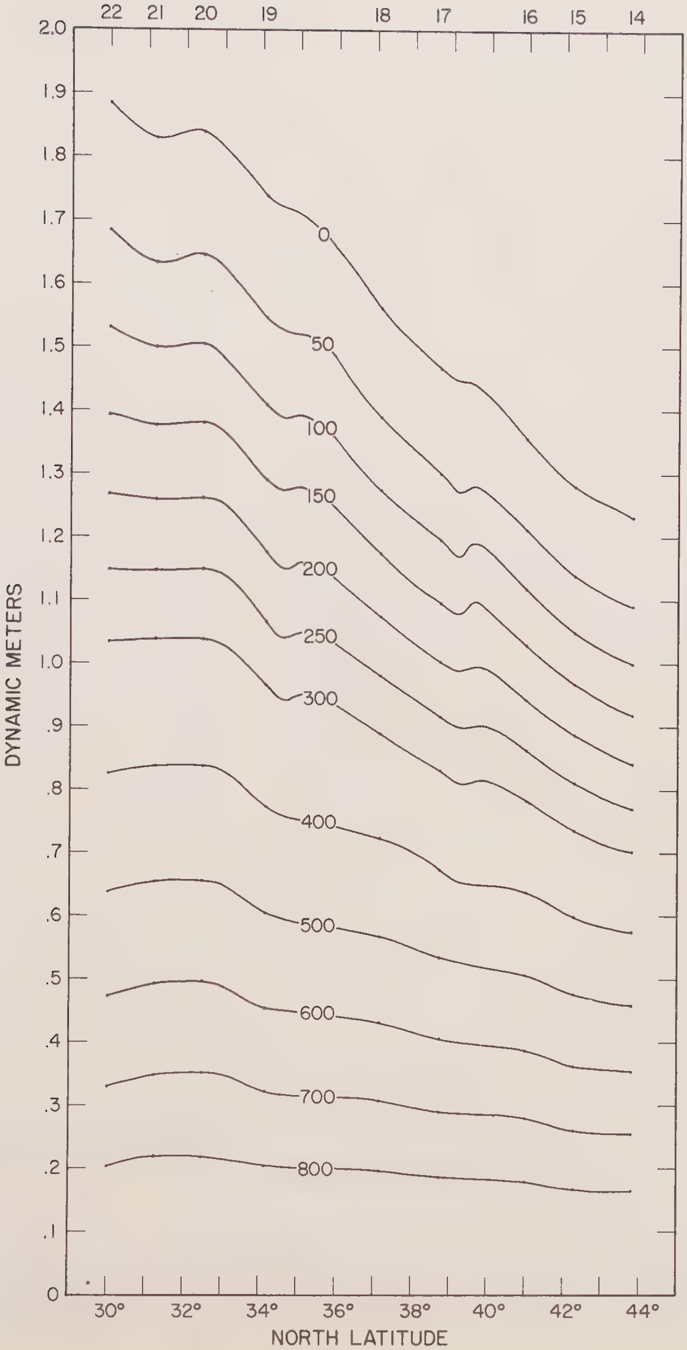


Figure 3.--Smoothed geopotential anomaly of the isobaric surfaces relative to the 1,000-db. surface along 170° W. longitude; *Charles H. Gilbert* cruise 17, stations 14-22, September-November 1954. Points represent computed values.

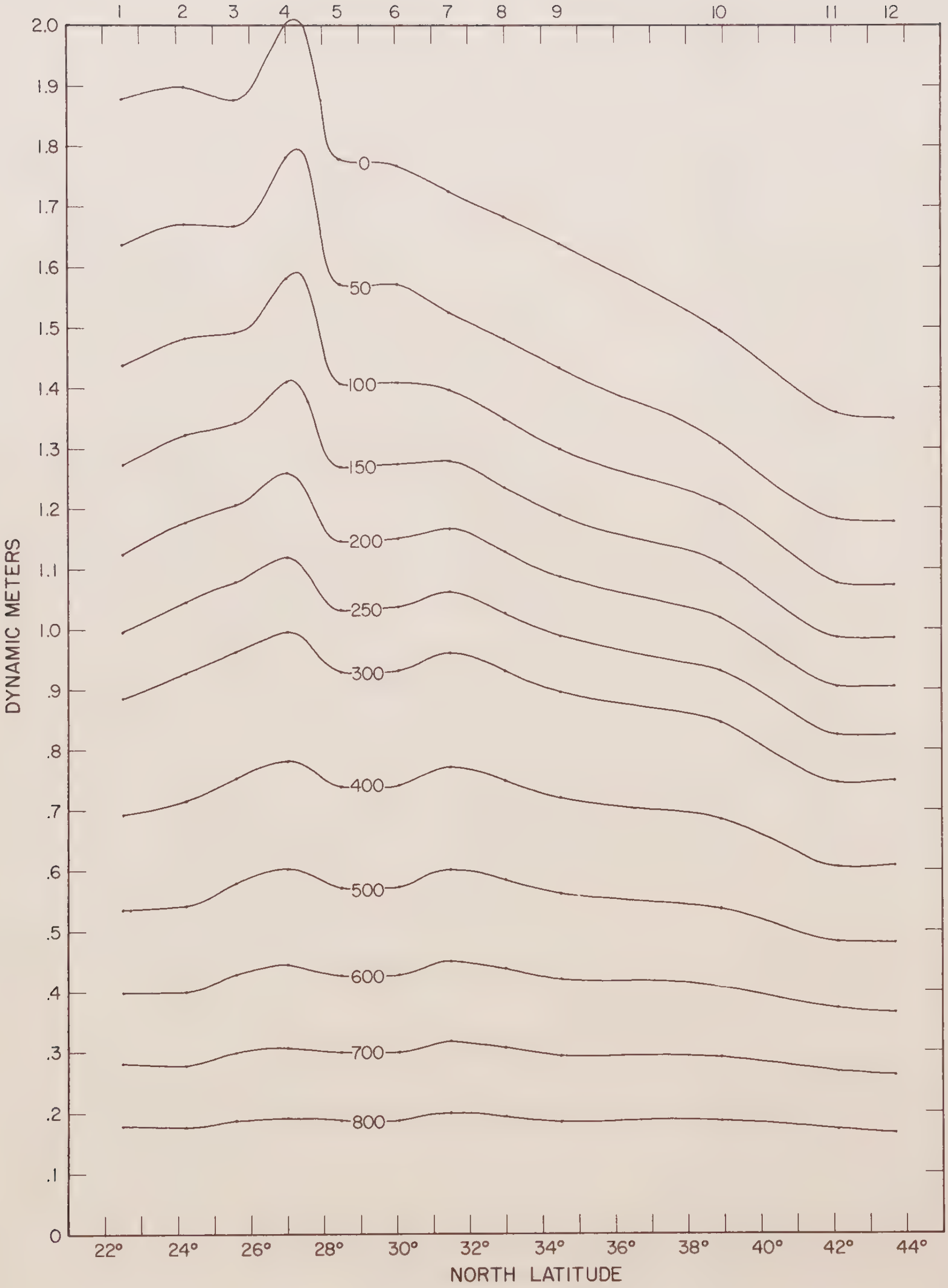


Figure 4.--Smoothed geopotential anomaly of the isobaric surfaces relative to the 1,000-db. surface along 160° W. longitude; Charles H. Gilbert cruise 17, stations 1-12, September-November 1954. Points represent computed values.

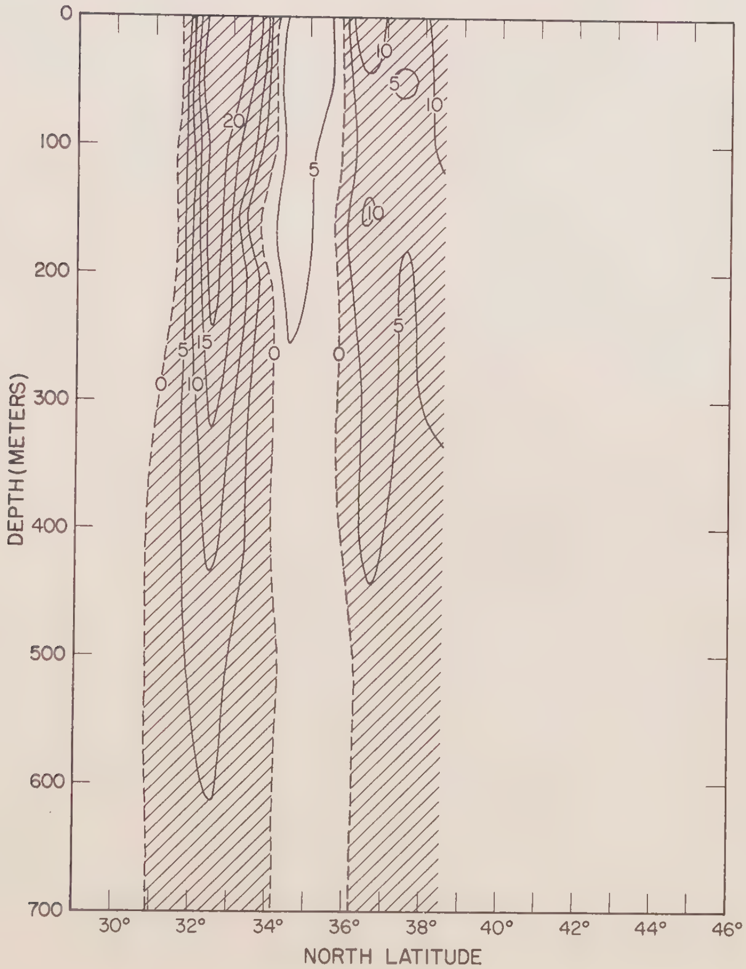


Figure 5. --Zonal components of the geostrophic currents in cm. per second across the 180th meridian; Charles H. Gilbert cruise 17, September-November 1954. Hatched areas indicate easterly flow. Contour interval 5 cm. /sec.

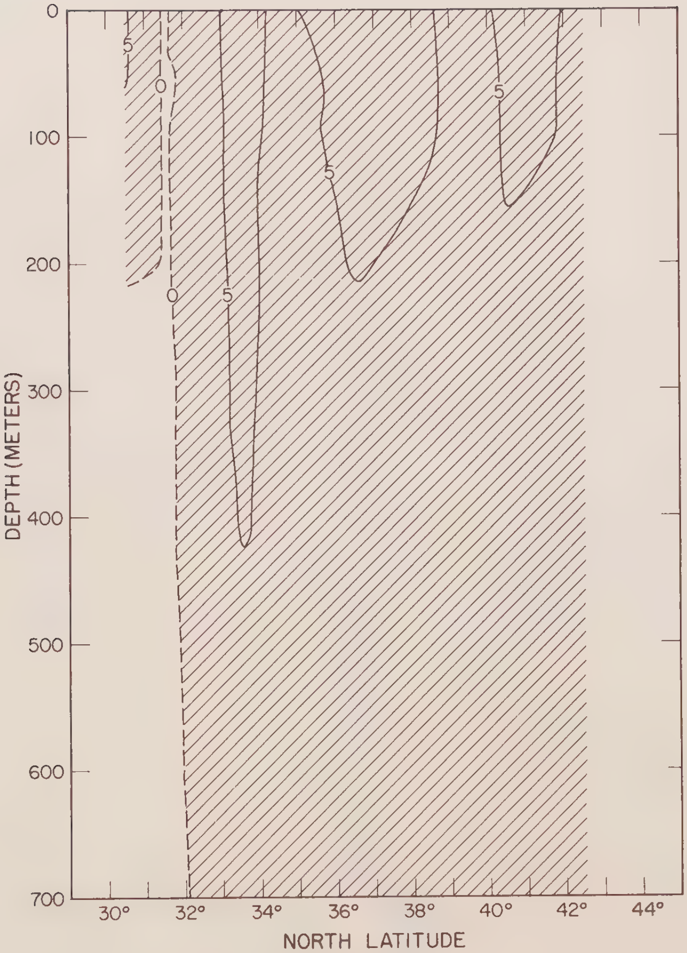


Figure 6.--Zonal components of the geostrophic currents in cm. per second across 170° W. longitude; Charles H. Gilbert cruise 17, September-November 1954. Hatched areas indicate easterly flow. Contour interval 5 cm. /sec.

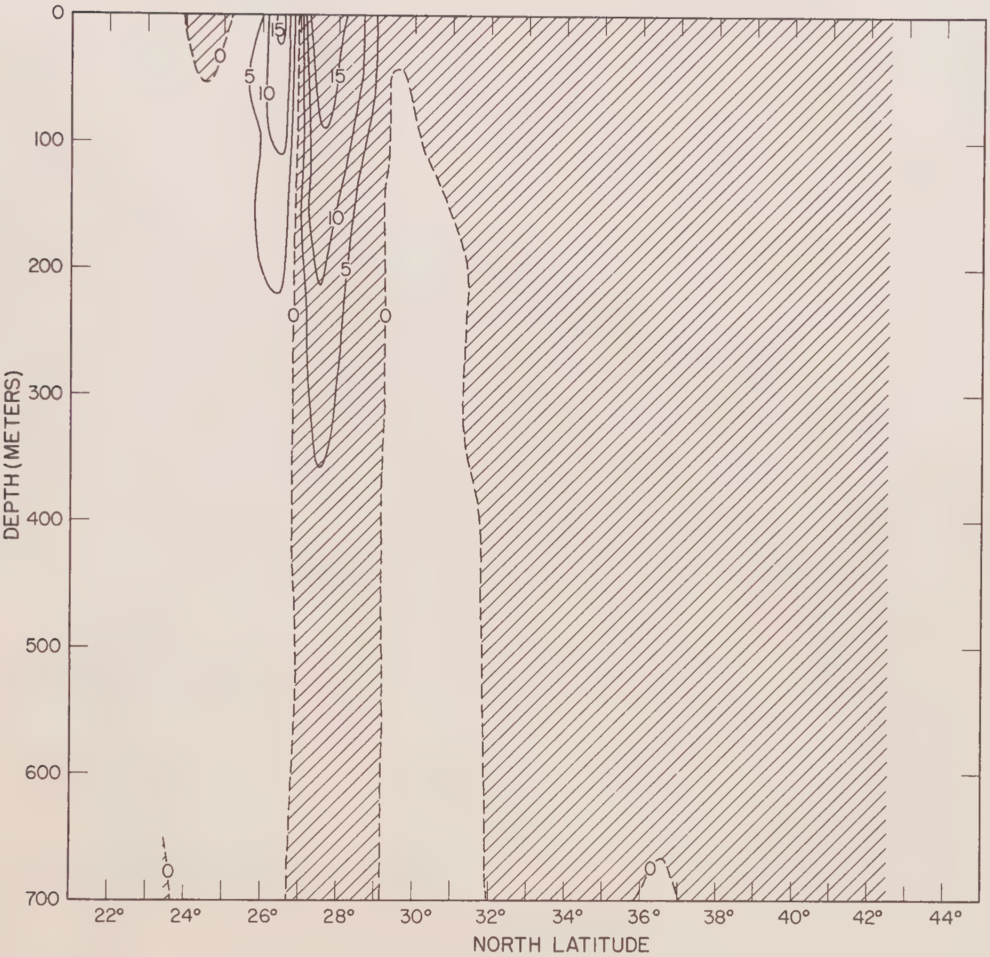
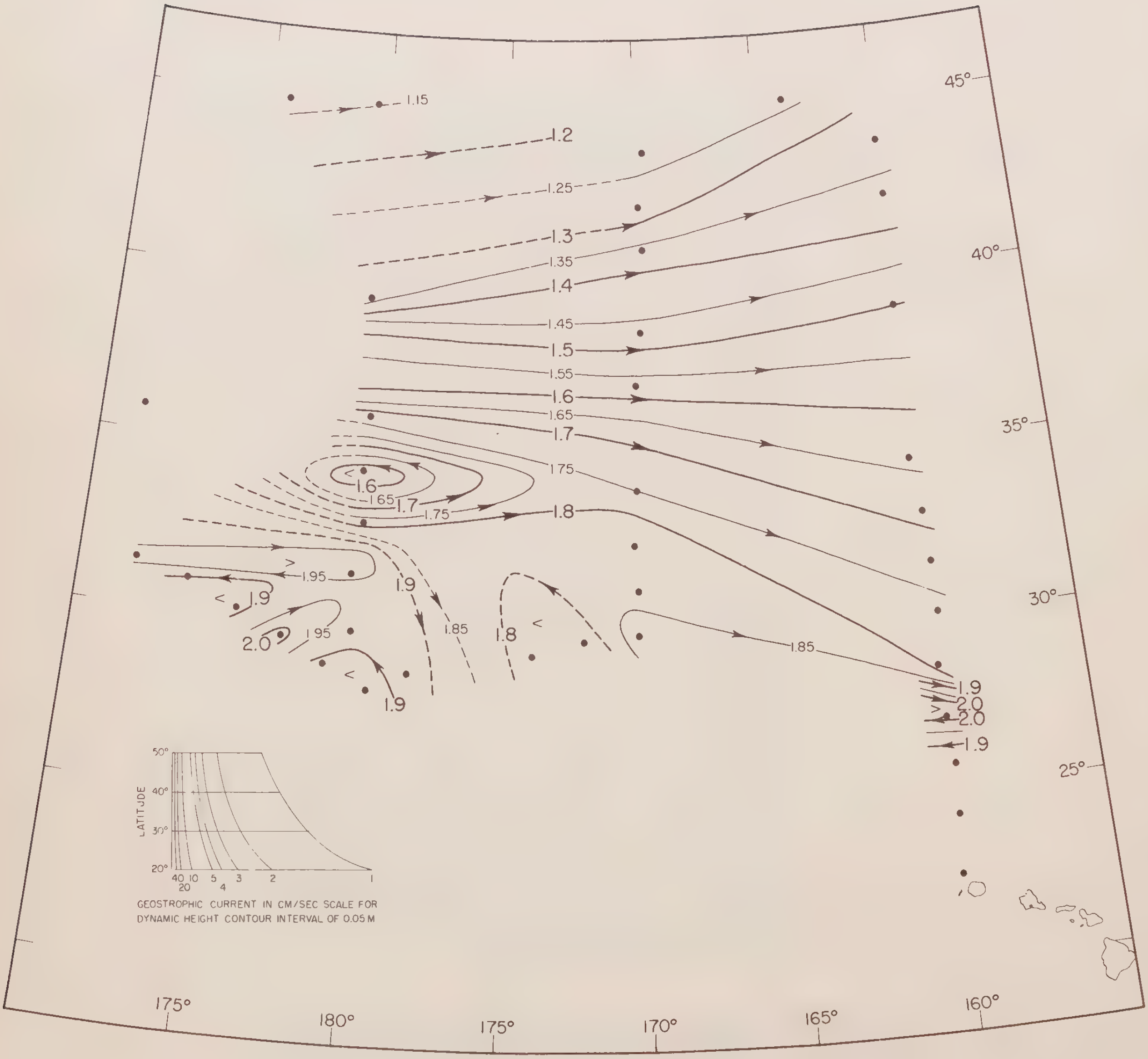


Figure 7.--Zonal components of the geostrophic currents in cm. per second across 160° W. longitude; Charles H. Gilbert cruise 17, September-November 1954. Hatched areas indicate easterly flow. Contour interval 5 cm./sec.



1.15
1.2
1.25
1.3
1.35
1.4
1.45
1.5
1.55
1.6
1.65
1.7
1.75
1.6
1.65
1.7
1.75
1.8
1.95
1.9
2.0
1.95
1.9
1.9
1.85
1.8
1.85
1.9
2.0
2.0
1.9
45°
40°
35°
30°
25°
50°
40°
30°
20°
LATITUDE
40 10 5 3 2 1
20 4
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR DYNAMIC HEIGHT CONTOUR INTERVAL OF 0.05 M
175°
180°
175°
170°
165°
160°

Figure 8.--Anomaly of the geopotential topography of the sea surface in dynamic meters relative to the 1,000-db. surface; *Charles H. Gilbert* cruise 17, September-November 1954. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.05 m.

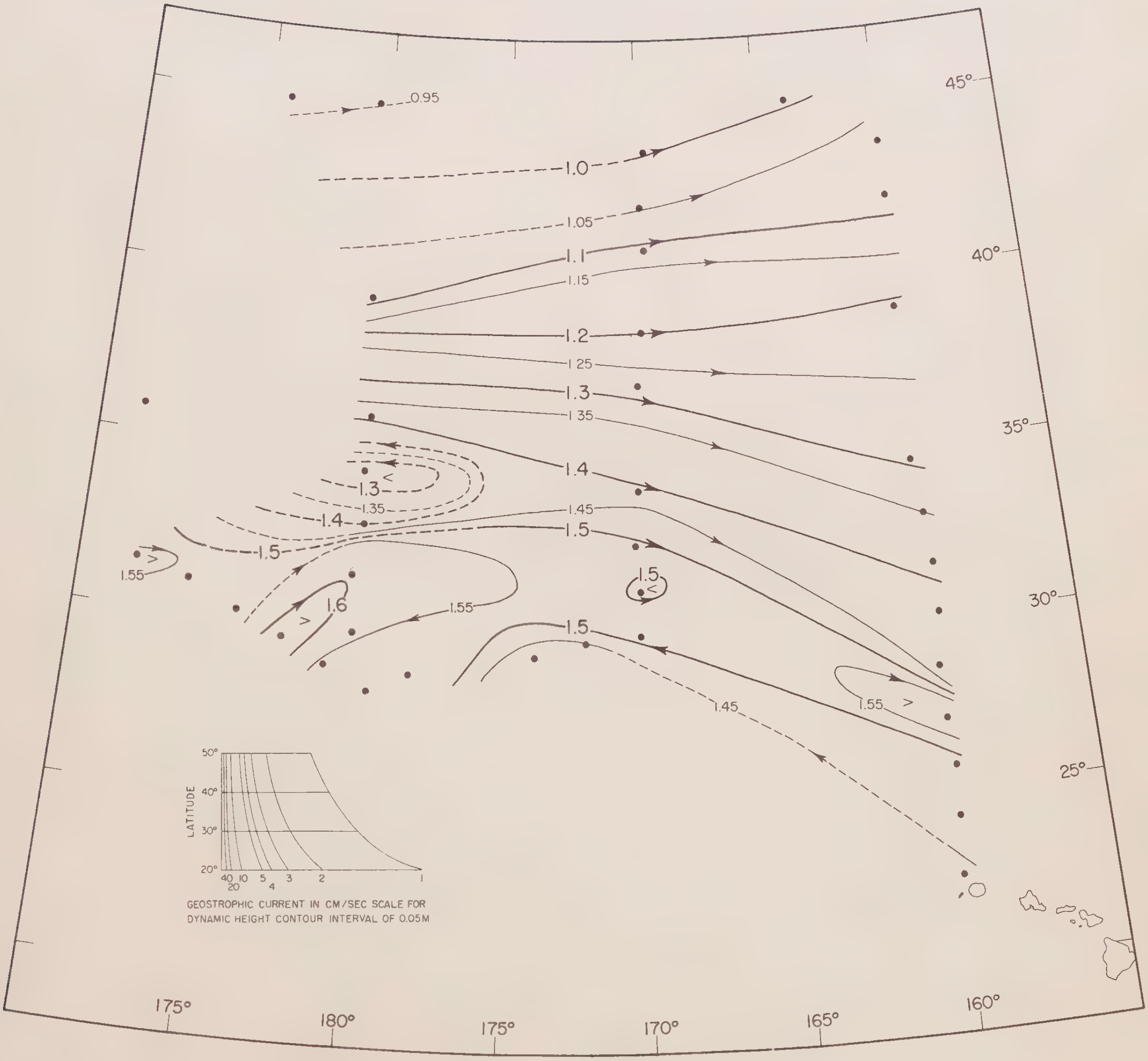

0.95
1.0
1.05
1.1
1.15
1.2
1.25
1.3
1.35
1.4
1.45
1.5
1.3
1.35
1.4
1.5
1.55
1.6
1.55
1.5
1.5
1.45
1.55
45°
40°
35°
30°
25°
175°
180°
175°
170°
165°
160°
50°
40°
30°
20°
LATITUDE
40 10 5 3 2 1
20 4
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR
DYNAMIC HEIGHT CONTOUR INTERVAL OF 0.05M

Figure 9.--Anonaly of the geopotential topography of the 100-db. surface in dynamic meters relative to the 1000-db. surface; Charles H. Gilbert cruise 17, September-November 1954. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.05 m.

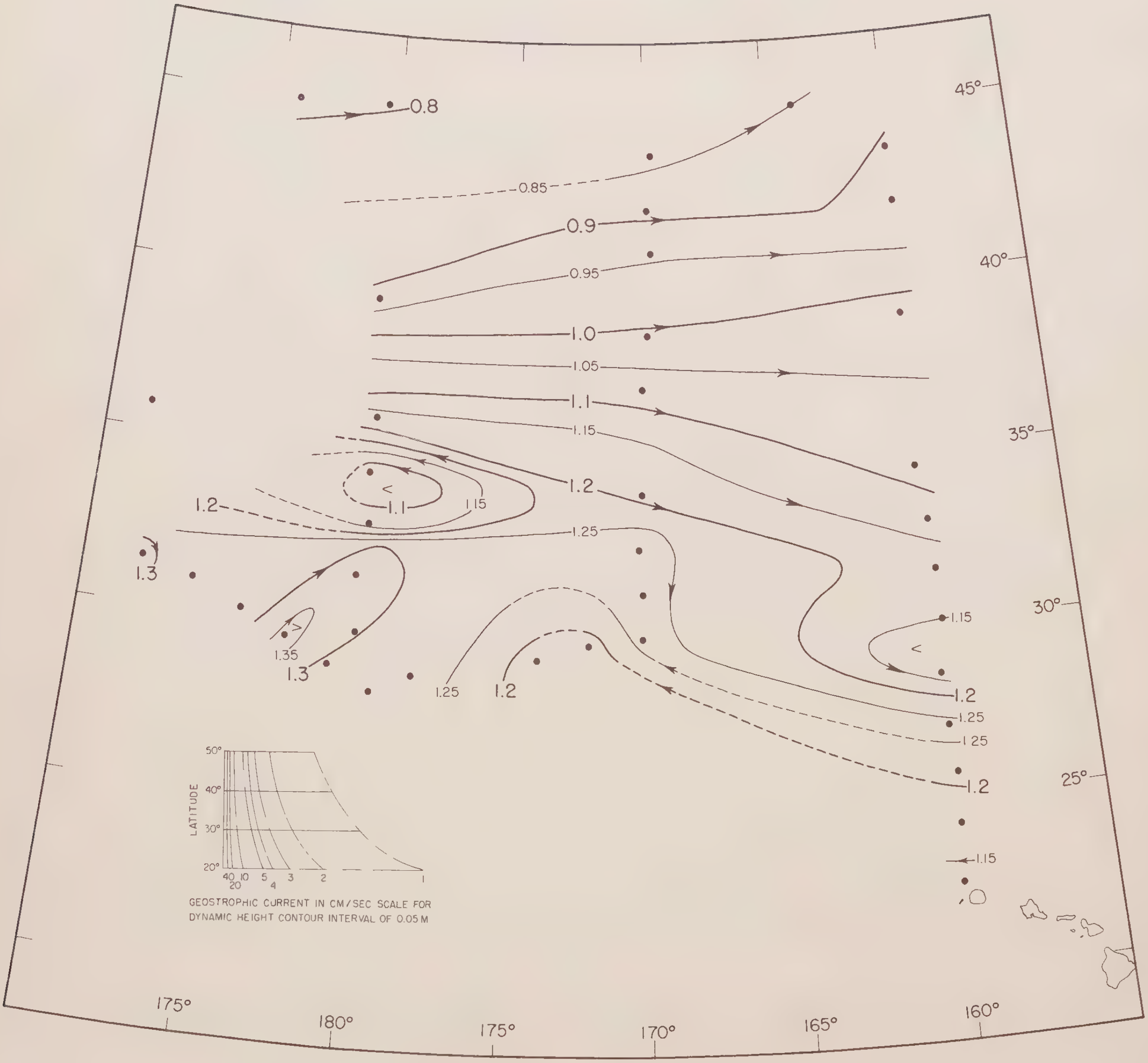

0.8
0.85
0.9
0.95
1.0
1.05
1.1
1.15
1.2
1.1
1.15
1.2
1.25
1.3
1.3
1.35
1.25
1.2
1.15
1.2
1.25
1.25
1.2
1.15
45°
40°
35°
30°
25°
175°
180°
175°
170°
165°
160°
50°
40°
30°
20°
LATITUDE
40 10 5 3 2 1
20 4
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR
DYNAMIC HEIGHT CONTOUR INTERVAL OF 0.05 M

Figure 10.--Anomaly of the geopotential topography of the 200-db. surface in dynamic meters relative to the 1000-db. surface; *Charles H. Gilbert* cruise 17, September-November 1954. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.05 m.

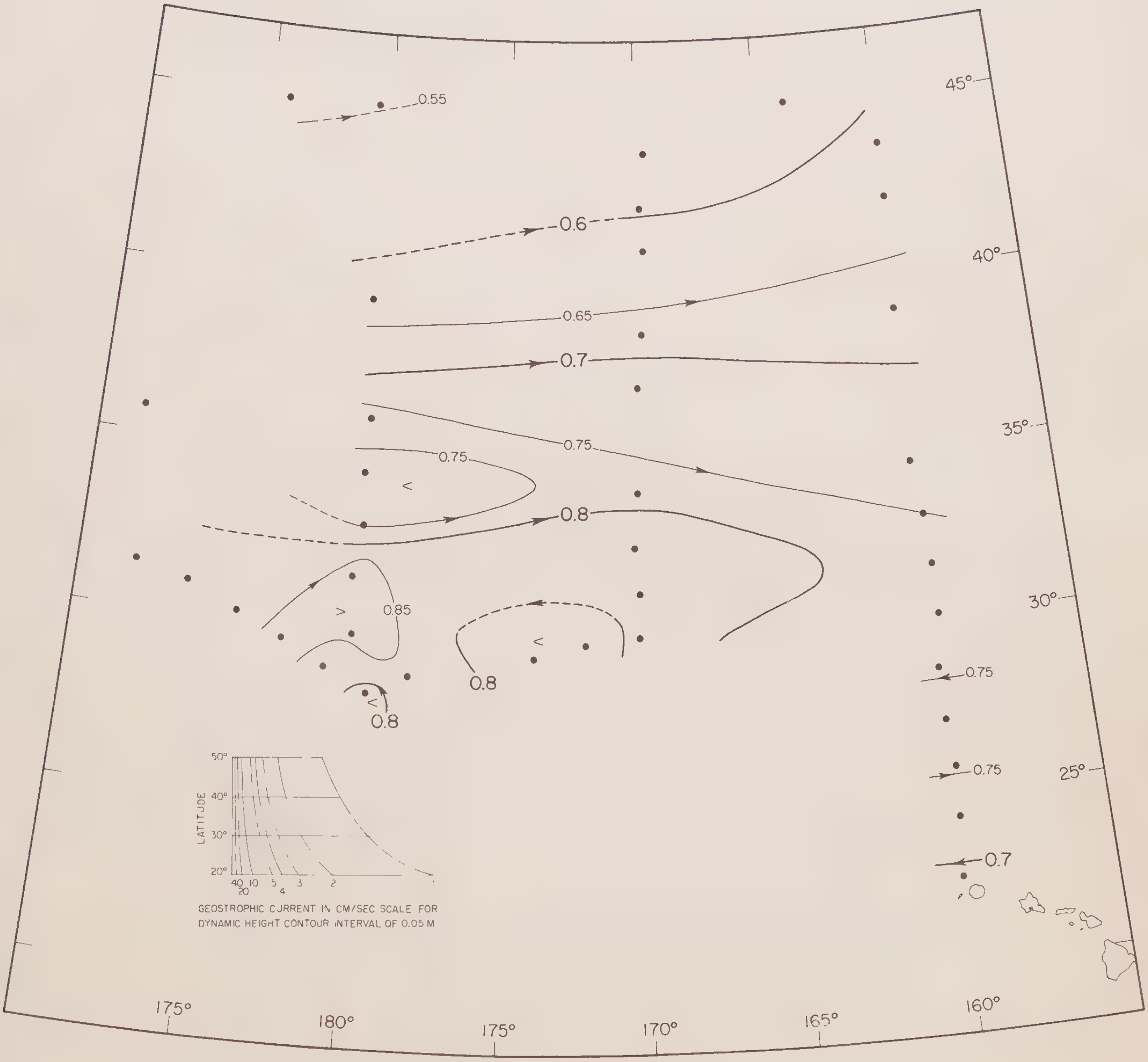

0.55
0.6
0.65
0.7
0.75
0.75
0.8
0.85
0.8
0.8
0.75
0.75
0.7
45°
40°
35°
30°
25°
175°
180°
175°
170°
165°
160°
50°
40°
30°
20°
LATITUDE
40
20
10
5
4
3
2
1
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR DYNAMIC HEIGHT CONTOUR INTERVAL OF 0.05 M

Figure 11.--Anomaly of the geopotential topography of the 400-db. surface in dynamic meters relative to the 1000-db. surface; Charles H. Gilbert cruise 17, September-November 1954. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.05 m.

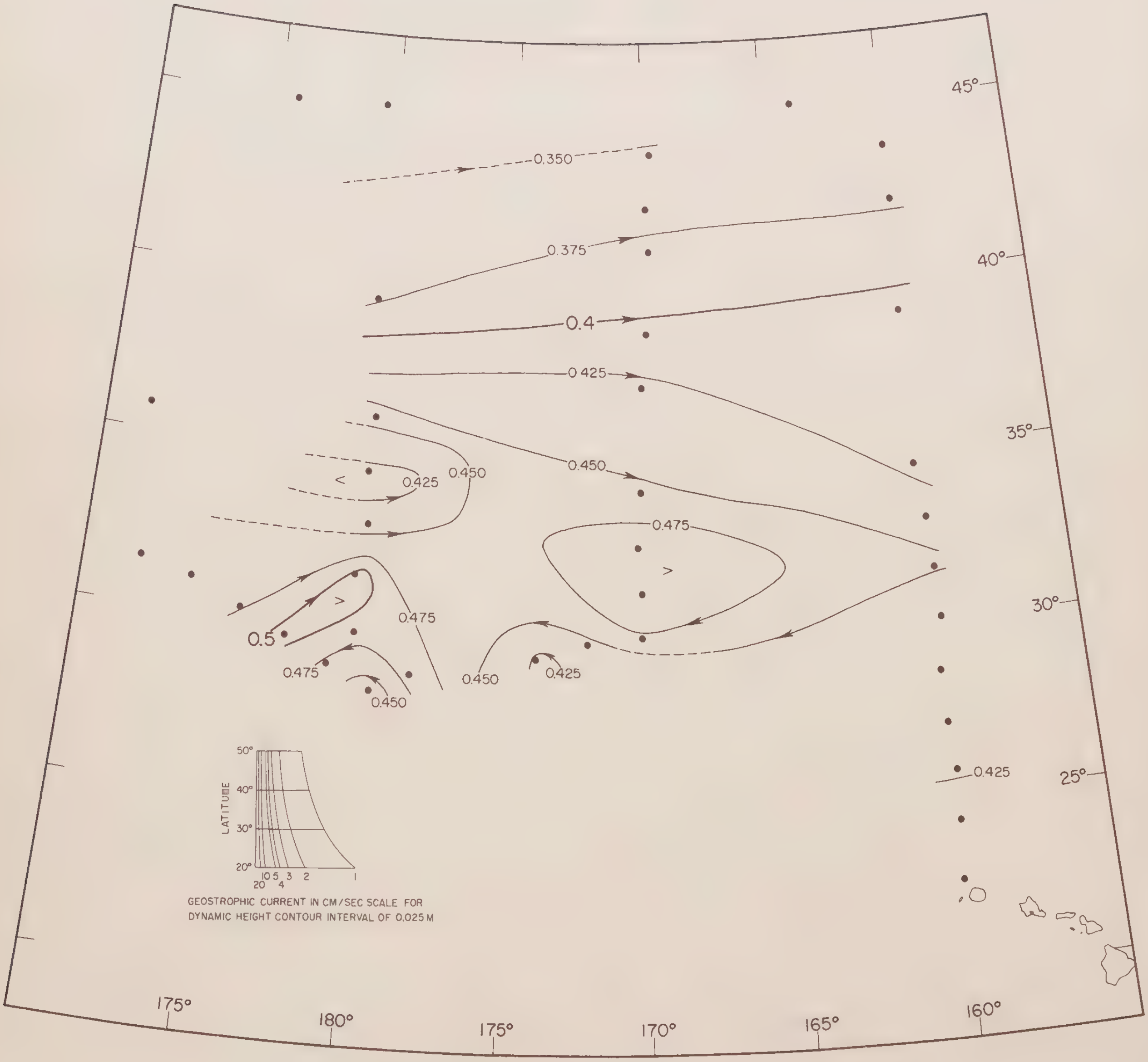
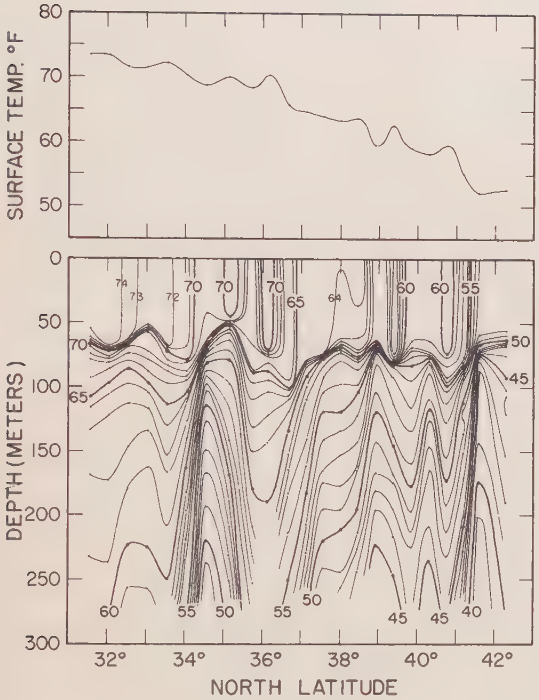

0.350
0.375
0.4
0.425
0.450
0.425
0.450
0.475
0.5
0.475
0.475
0.450
0.450
0.425
0.425
45°
40°
35°
30°
25°
175°
180°
175°
170°
165°
160°
50°
40°
30°
20°
LATITUDE
10 5 3 2 1
20 4
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR DYNAMIC HEIGHT CONTOUR INTERVAL OF 0.025 M

Figure 12.--Anomaly of the geopotential topography of the 600-db. surface in dynamic meters relative to the 1000-db. surface; Charles H. Gilbert cruise 17, September-November 1954. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.025 m.



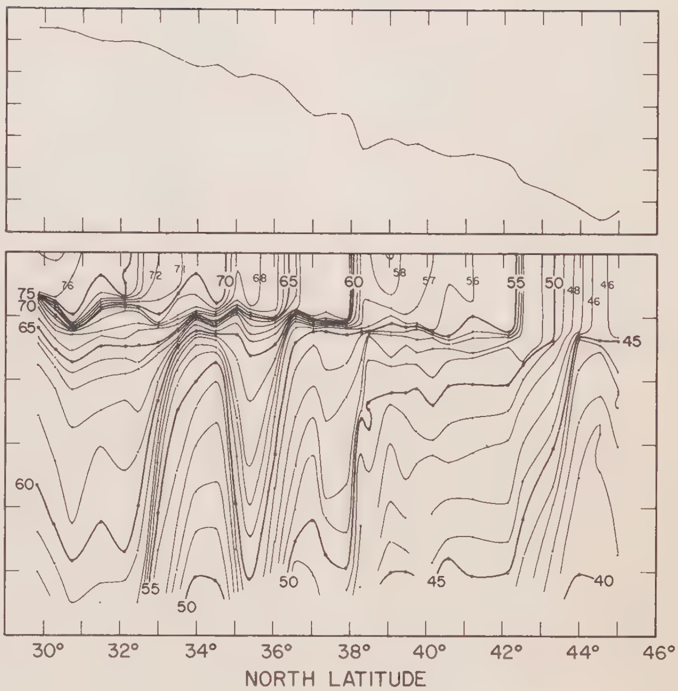
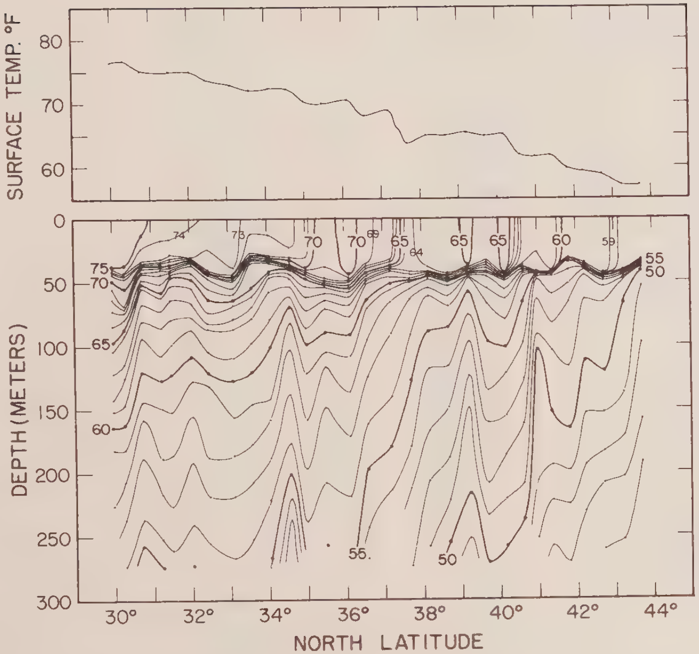


Figure 13.--Surface (bucket) temperature (upper panel) and temperature-depth section (lower panel) in degrees Fahrenheit along 172°E. longitude from BT observations; Charles H. Gilbert cruise 17, September-November 1954. Small dashes indicate the depth of lowering. Contour interval 1°F.

Figure 14.--Same along the 180th meridian.



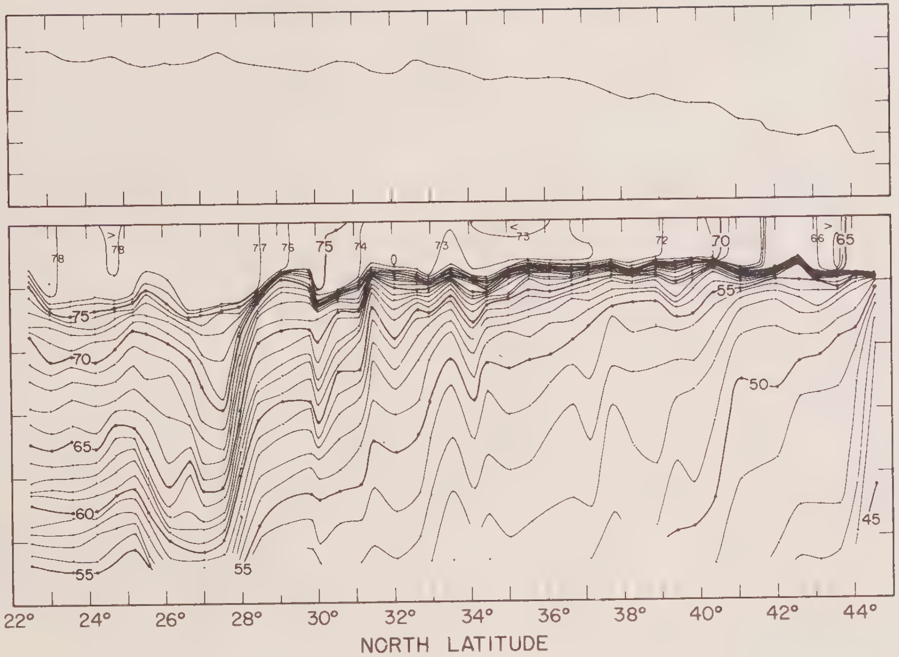
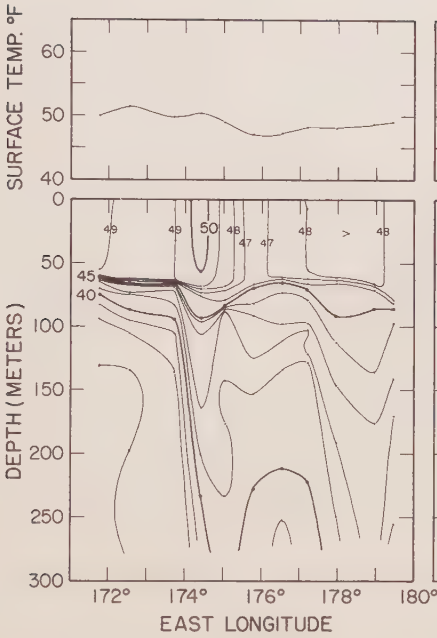


Figure 15.--Surface (bucket) temperature (upper panel) and temperature-depth section (lower panel) in degrees Fahrenheit along 170°W. longitude from BT observations; Charles H. Gilbert cruise 17, September-November 1954. Small dashes indicate the depth of lowering. Contour interval 1°F.

Figure 16.--Same along 160°W. longitude.



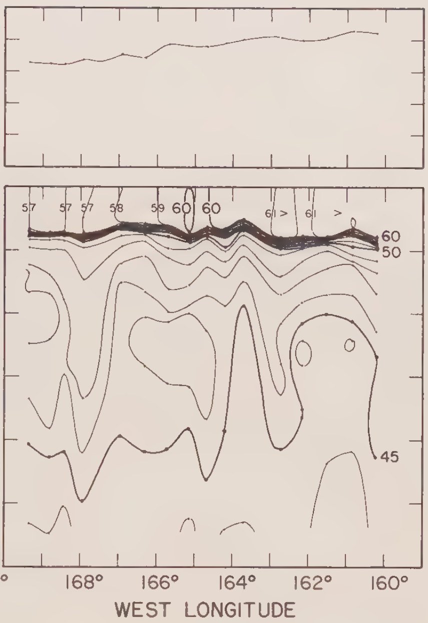


Figure 17.--Surface (bucket) temperature (upper panel) and temperature-depth section (lower panel) in degrees Fahrenheit along 45°N. latitude between 172°E. and the 180th meridian from BT observations (lower panel); Charles H. Gilbert cruise 17, September-November 1954.

Figure 18.--Same along 45°N. between 160° and 170°W. longitude.

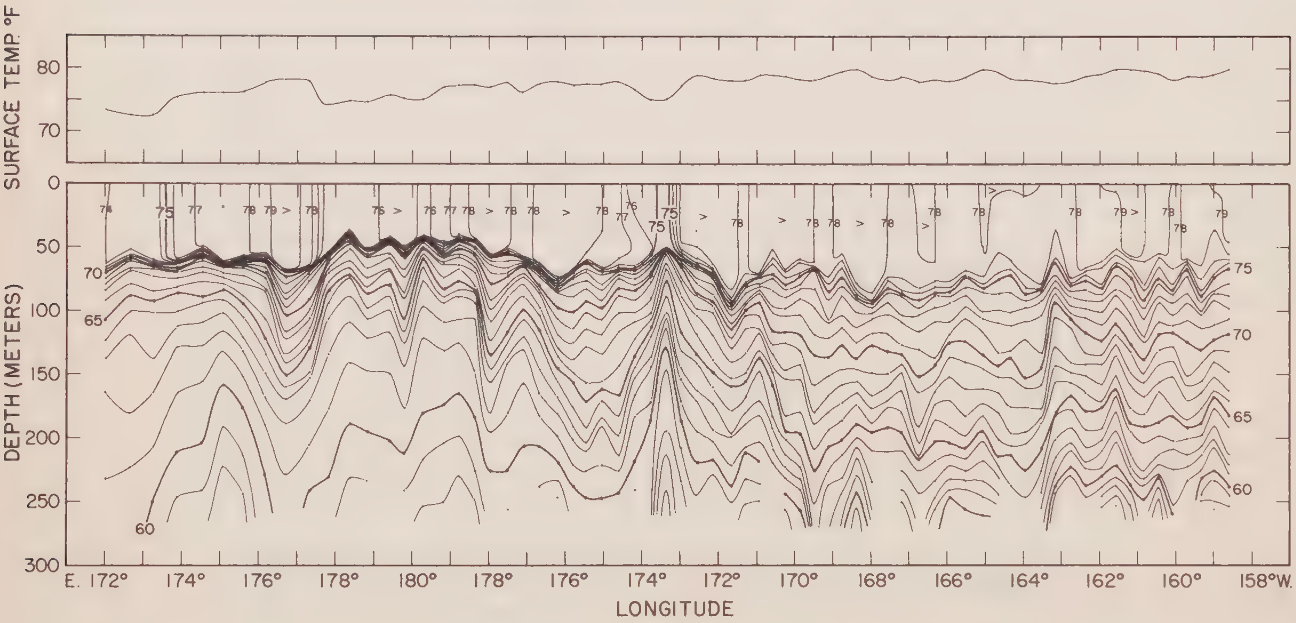


Figure 19.--Surface (bucket) temperatures (upper panel) and temperature-depth section (lower panel) in degrees Fahrenheit from 31°23'N., 172°E. to 21°23'N., 158°35'W. from BT observations; Charles H. Gilbert cruise 17, September-November 1954. Contour interval 1°F.

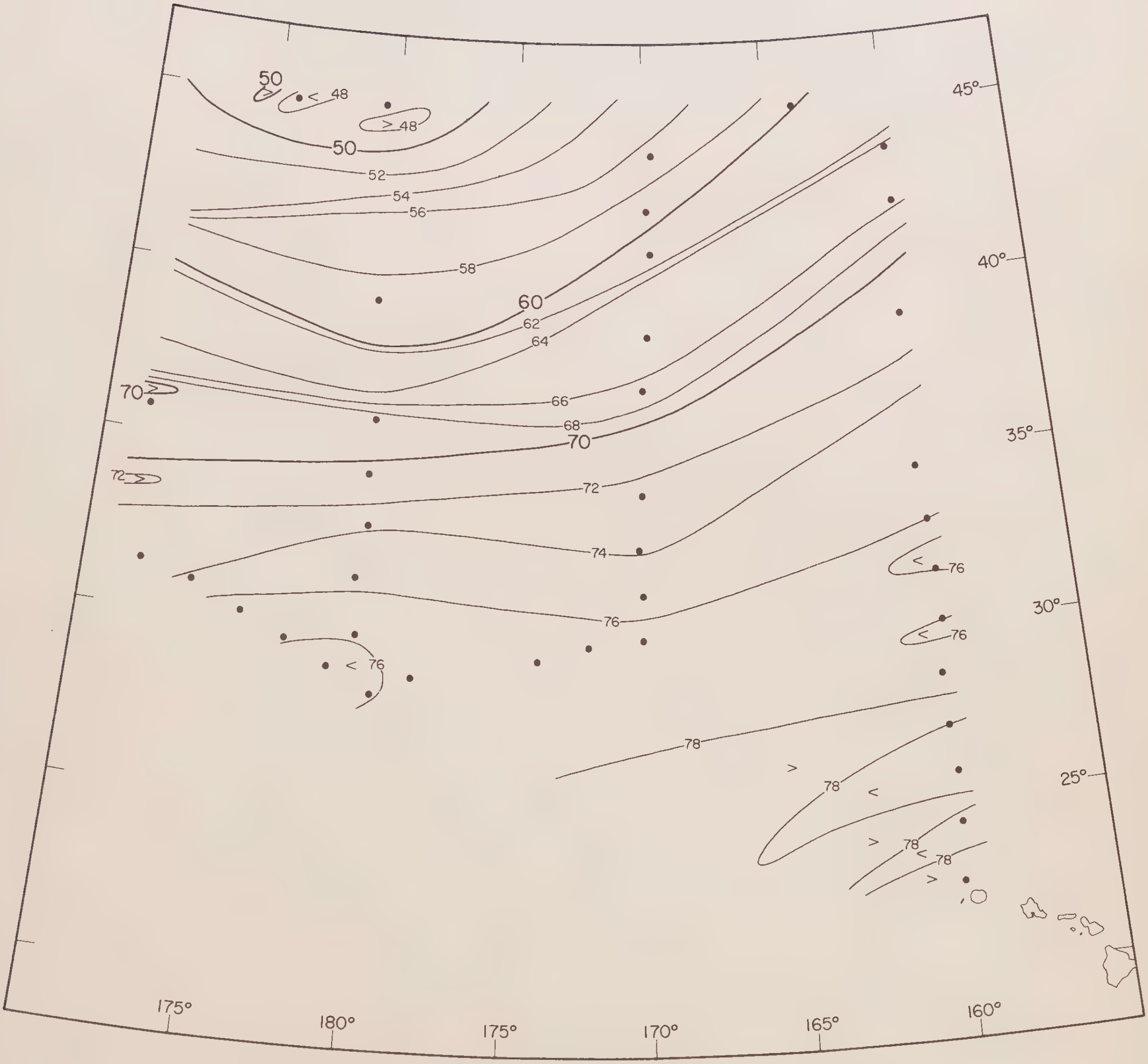

50
48
48
50
52
54
56
58
60
62
64
66
68
70
70
72
72
74
76
76
76
76
78
78
78
78
45°
40°
35°
30°
25°
175°
180°
175°
170°
165°
160°

Figure 20.--Surface (bucket) temperatures in degrees Fahrenheit; Charles H. Gilbert cruise 17, September-November 1954. Contour interval 2°F.

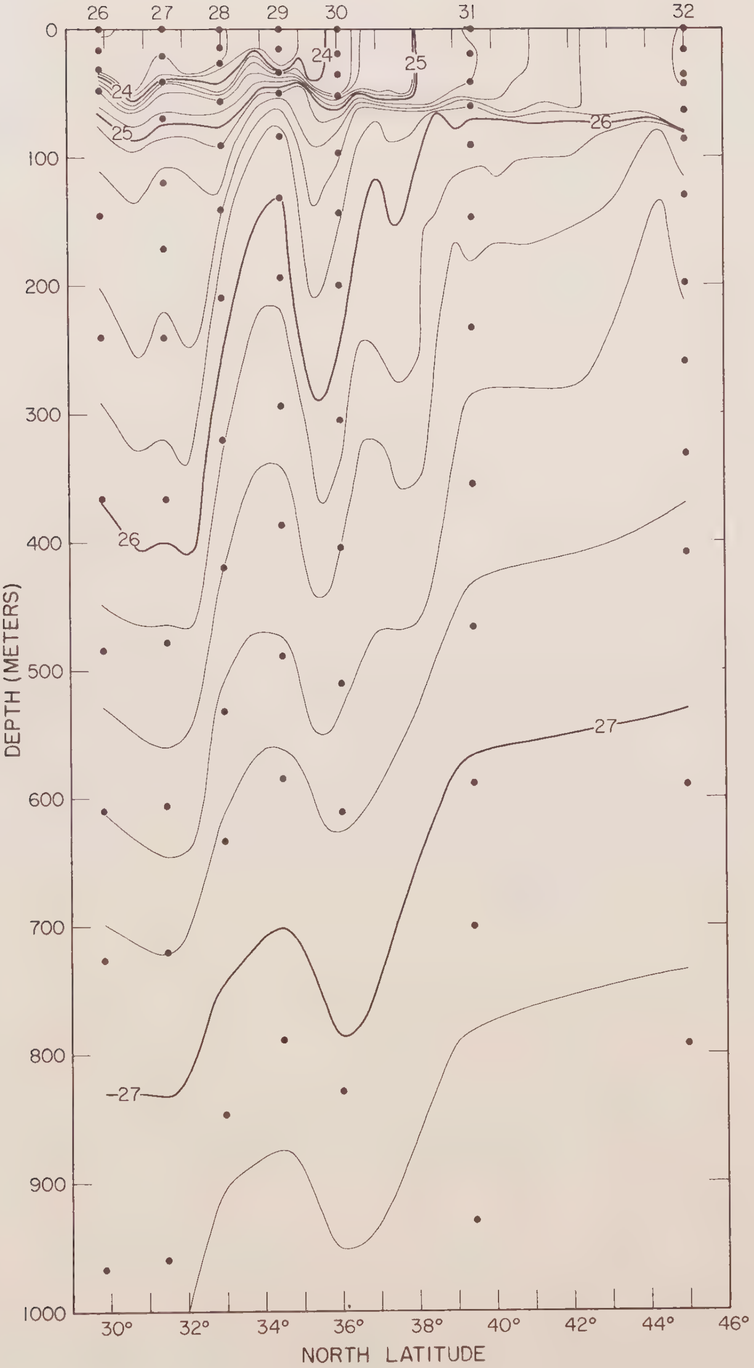


Figure 21.--Vertical section of sigma-t along the 180th meridian; Charles H. Gilbert cruise 17, stations 26-32, September-November 1954. Contour interval 0.2. Points indicate observed values.

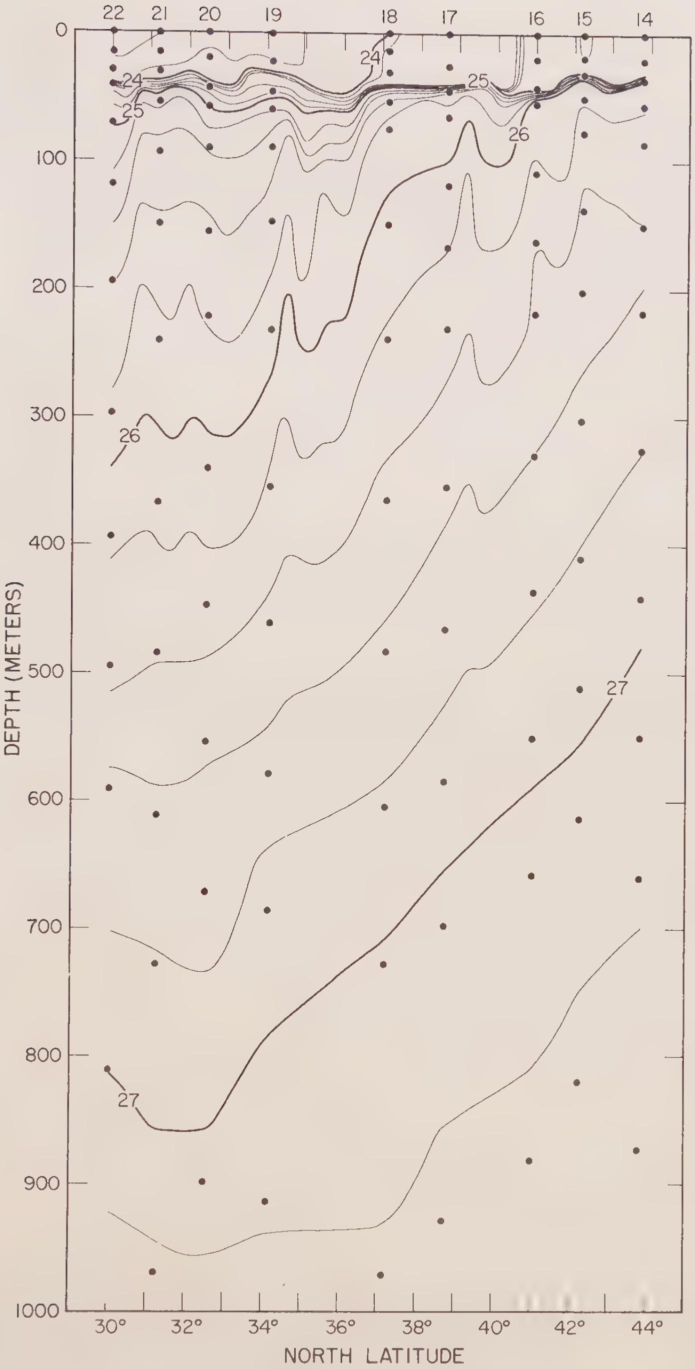


Figure 22.--Vertical section of sigma-t along 170°W. longitude; Charles H. Gilbert cruise 17, stations 14-22, September-November 1954. Contour interval 0.2. Points indicate observed values.

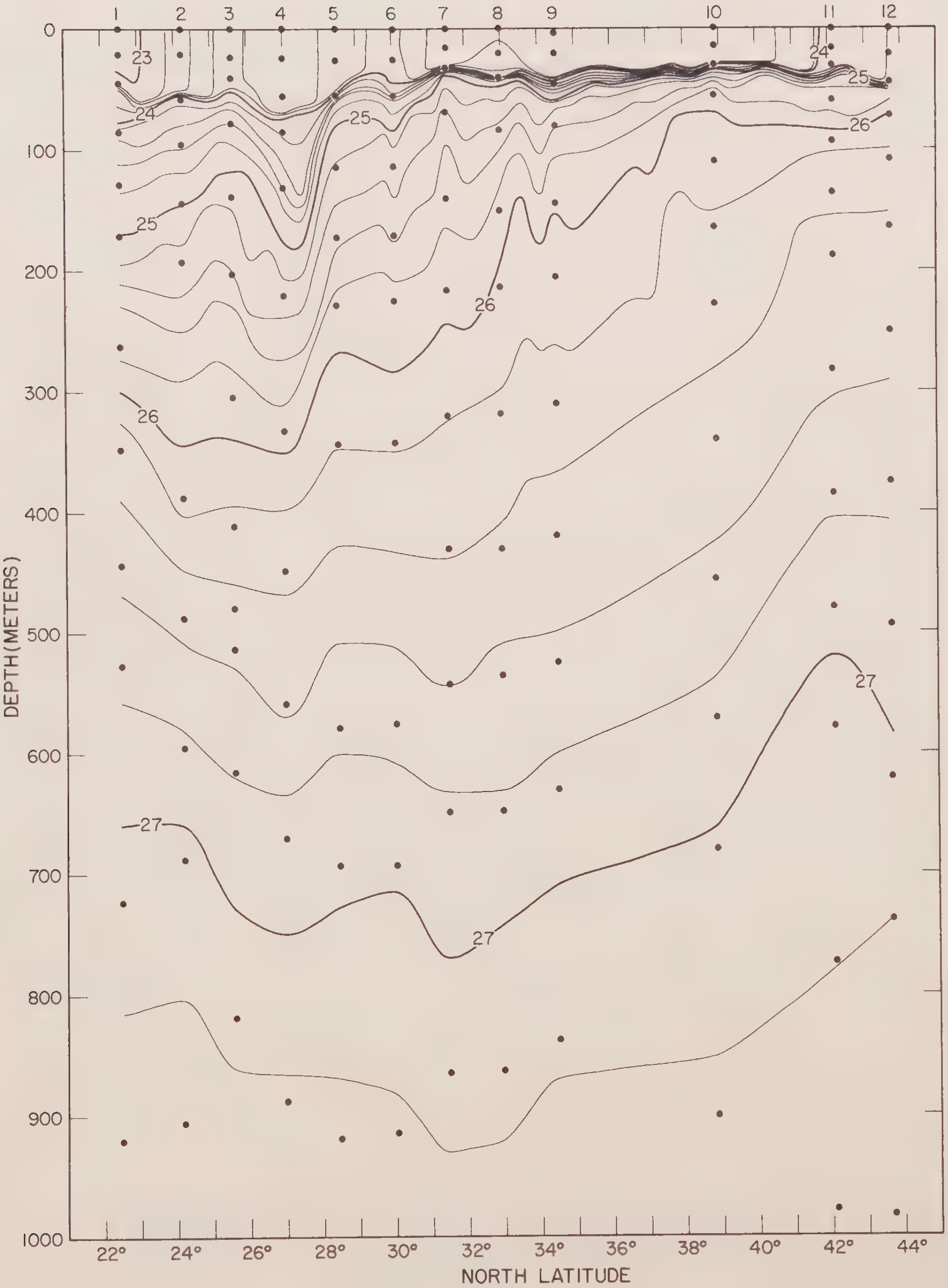


Figure 23.--Vertical section of sigma-t along 160°W. longitude; Charles H. Gilbert cruise 17, stations 1-12, September-November 1954. Contour interval 0.2. Points indicate observed values.

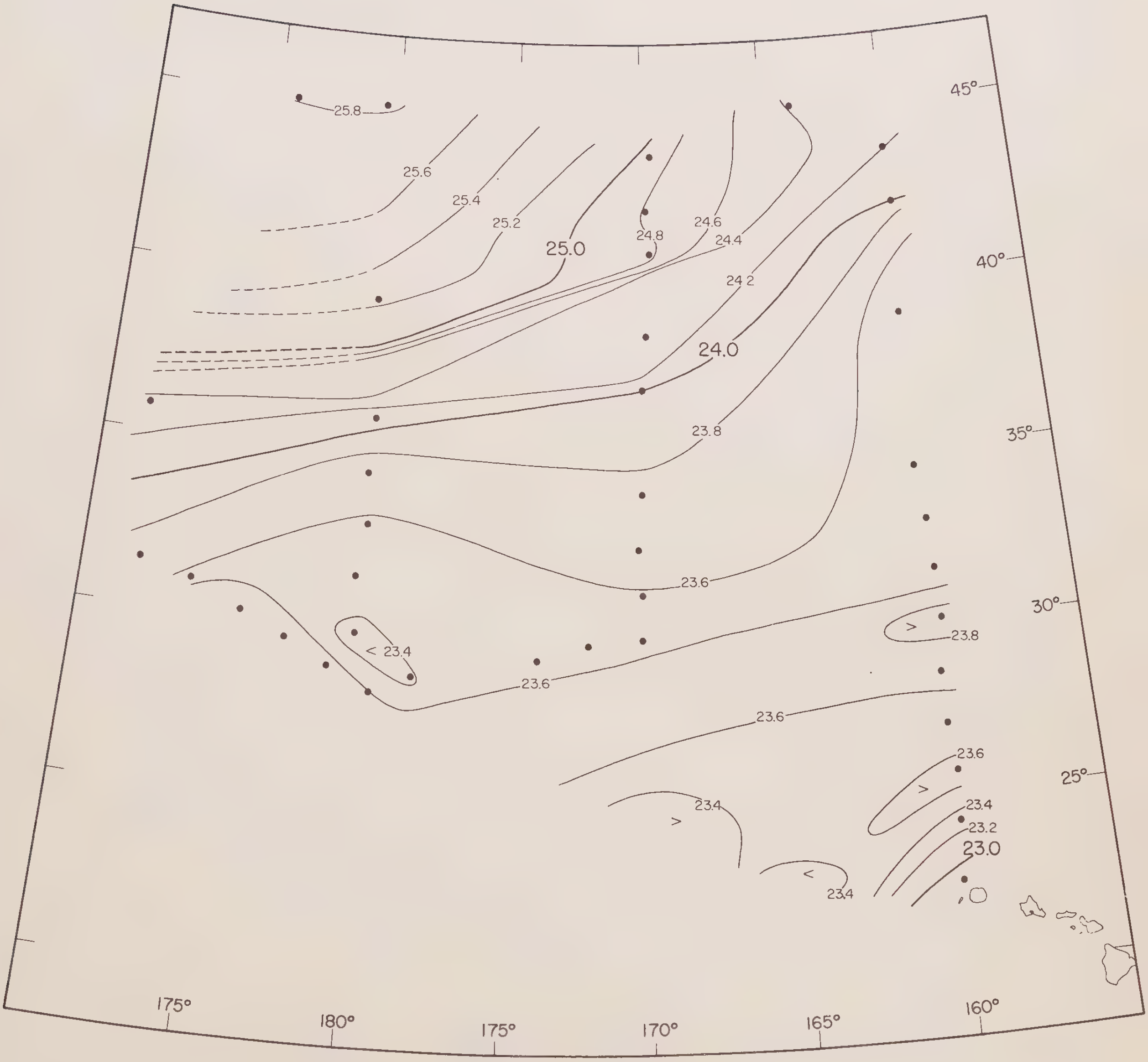

45°
40°
35°
30°
25°
25.8
25.6
25.4
25.2
25.0
24.8
24.6
24.4
24.2
24.0
23.8
23.6
< 23.4
23.6
23.6
>
23.8
23.6
>
23.4
23.2
23.0
23.4
>
<
23.4
175°
180°
175°
170°
165°
160°

Figure 24.--Surface sigma-t, *Charles H. Gilbert* cruise 17, September-November 1954. Contour interval 0.2. Dots indicate station positions.

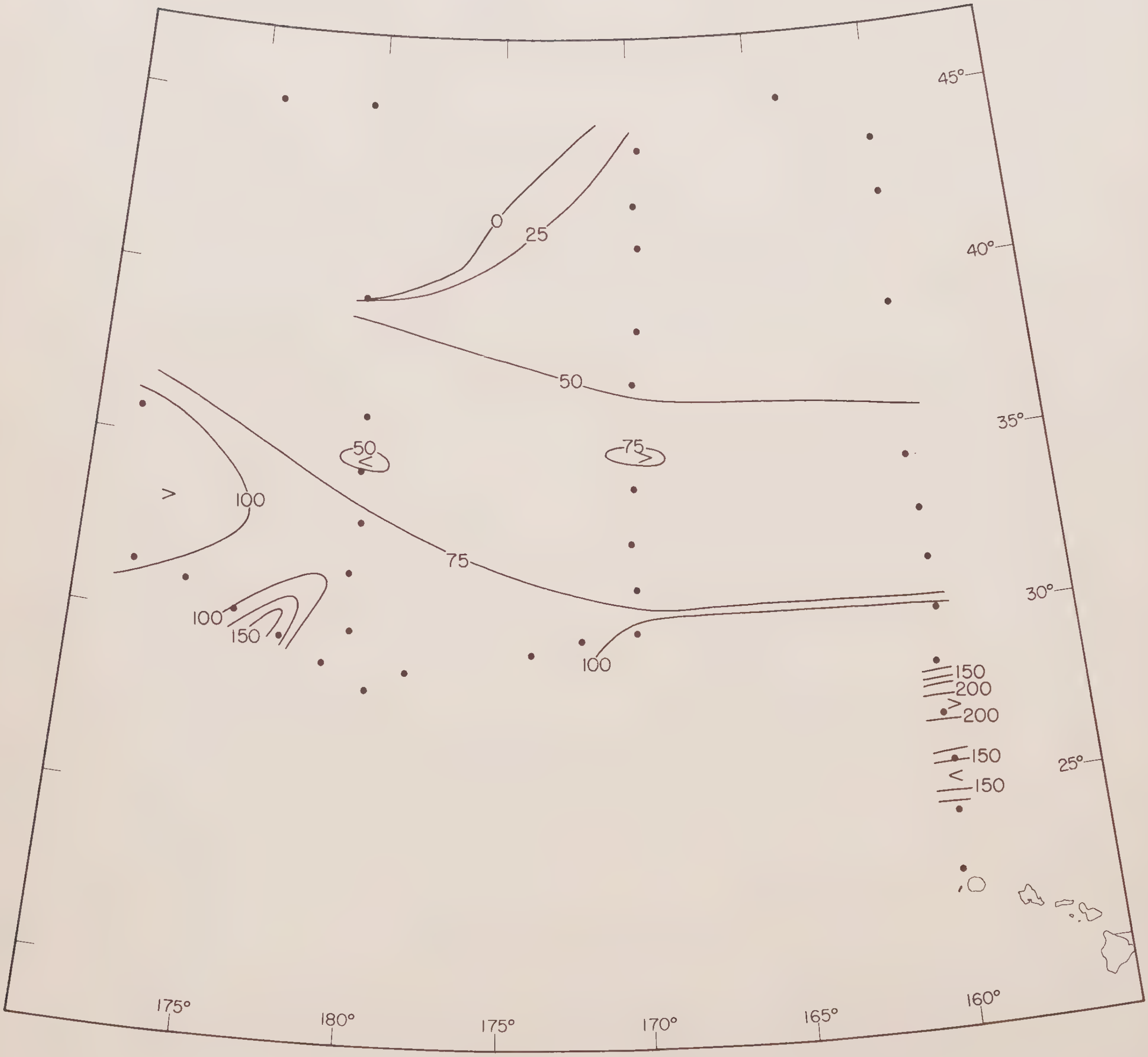

45°
40°
35°
30°
25°
0
25
50
50
75
75
100
100
150
100
150
200
200
150
150
175°
180°
175°
170°
165°
160°

Figure 25.--Depth of the 25.2 sigma-t surface in meters, Charles H. Gilbert cruise 17, September-November 1954. Contour interval 25 m. Dots indicate station positions.

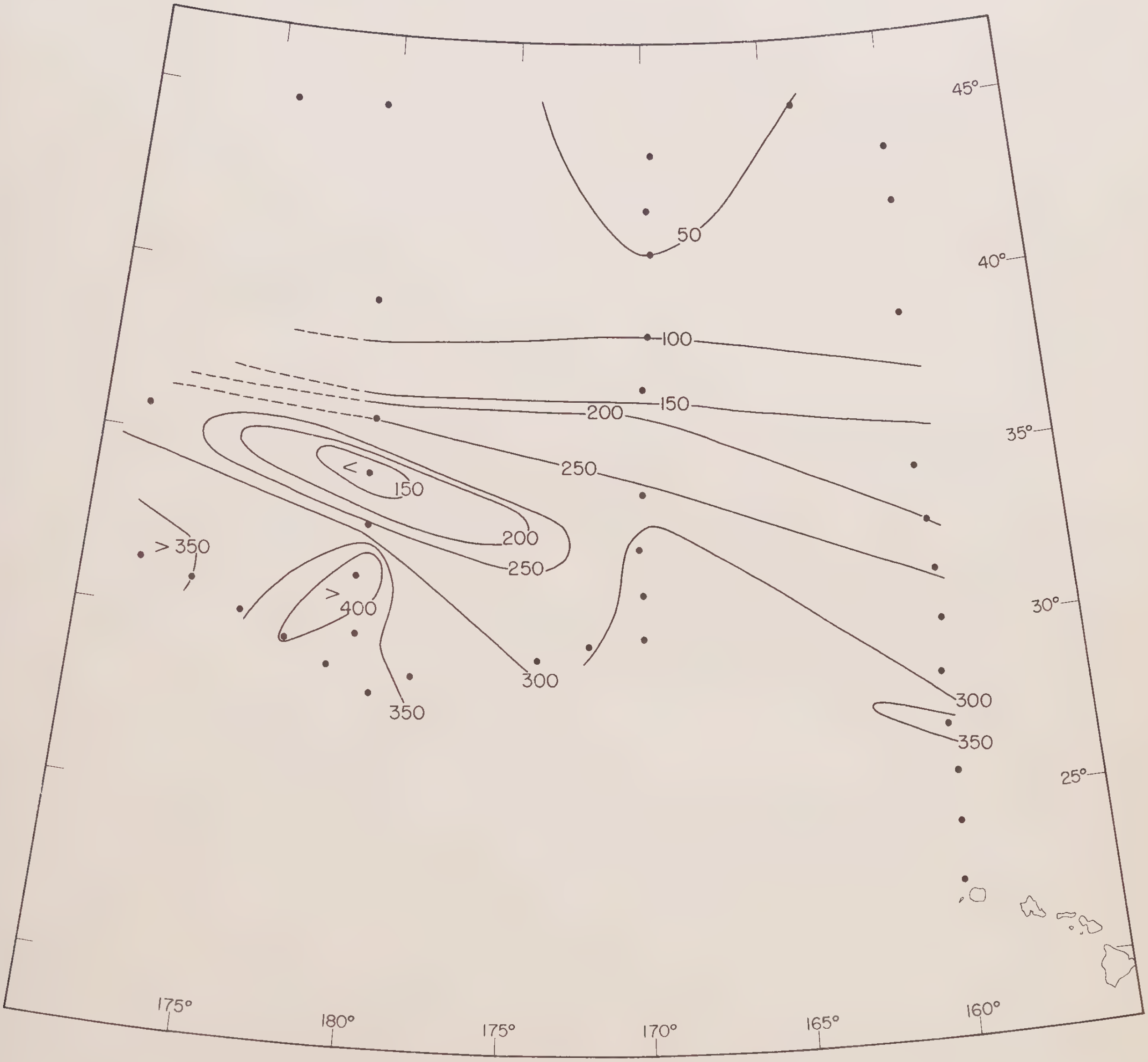
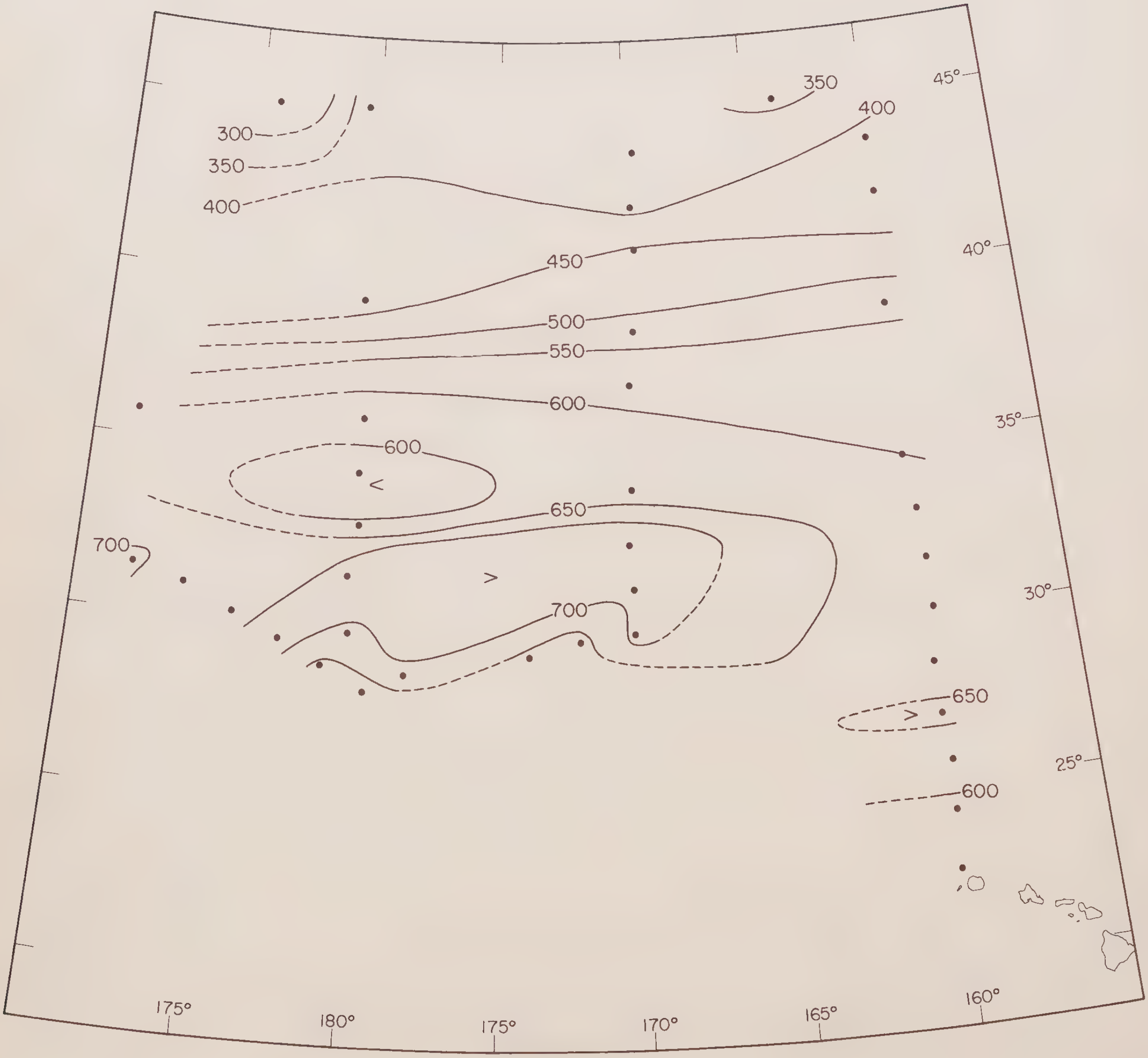

45°
50
40°
100
150
200
35°
250
< 150
200
250
> 350
30°
> 400
300
350
300
350
25°
175°
180°
175°
170°
165°
160°

Figure 26.--Depth of the 26.0 sigma-t surface in meters; *Charles H. Gilbert* cruise 17, September-November 1954. Contour interval 50 m. Dots indicate station positions.



45°
40°
35°
30°
25°
160°
165°
170°
175°
180°
175°
300
350
400
350
400
450
500
550
600
600
650
700
700
650
600

Figure 27.--Depth of the 26.8 sigma-t surface in meters; Charles H. Gilbert cruise 17, September-November 1954. Contour interval 50 m. Dots indicate station positions.

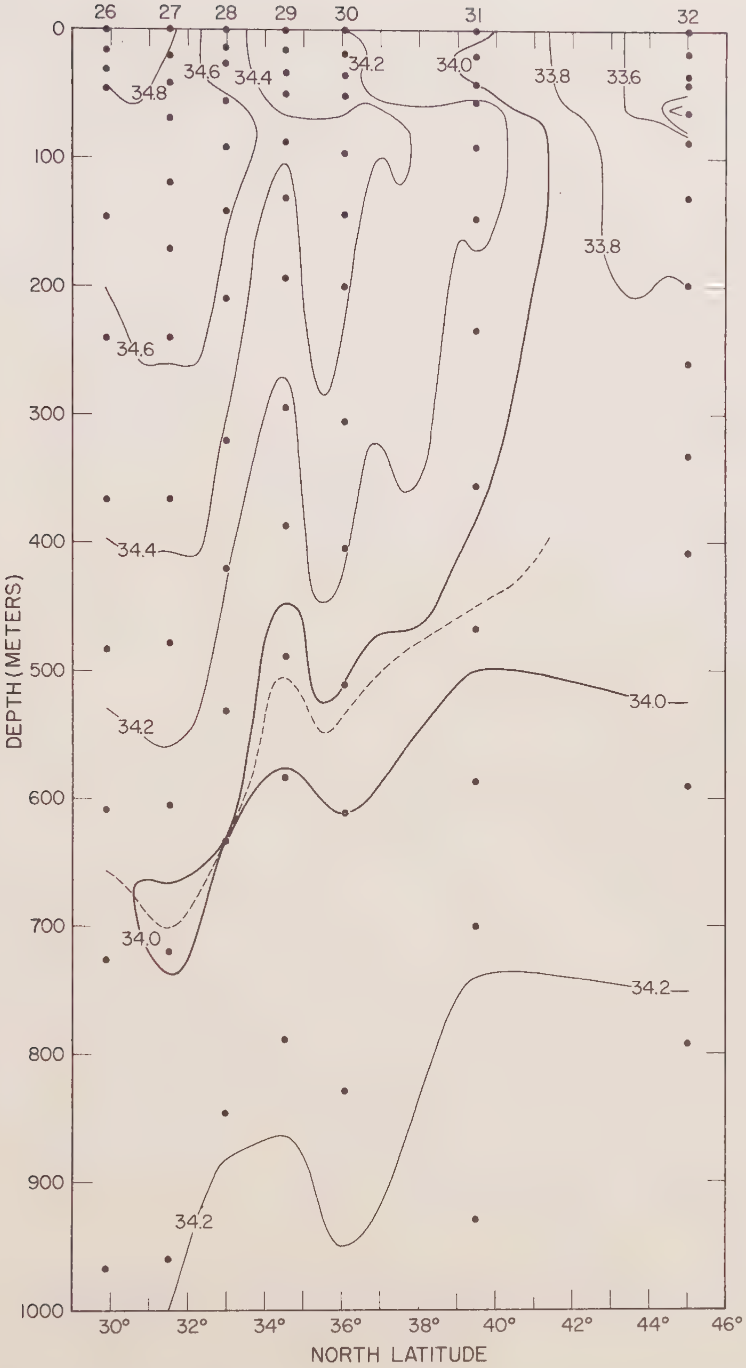


Figure 28.--Vertical section of salinity in parts per thousand along the 180th meridian; Charles H. Gilbert cruise 17, stations 26-32, September-November 1954. Contour interval 0.2 ‰. Points indicate observed values. Dotted line indicates depth of salinity minima.

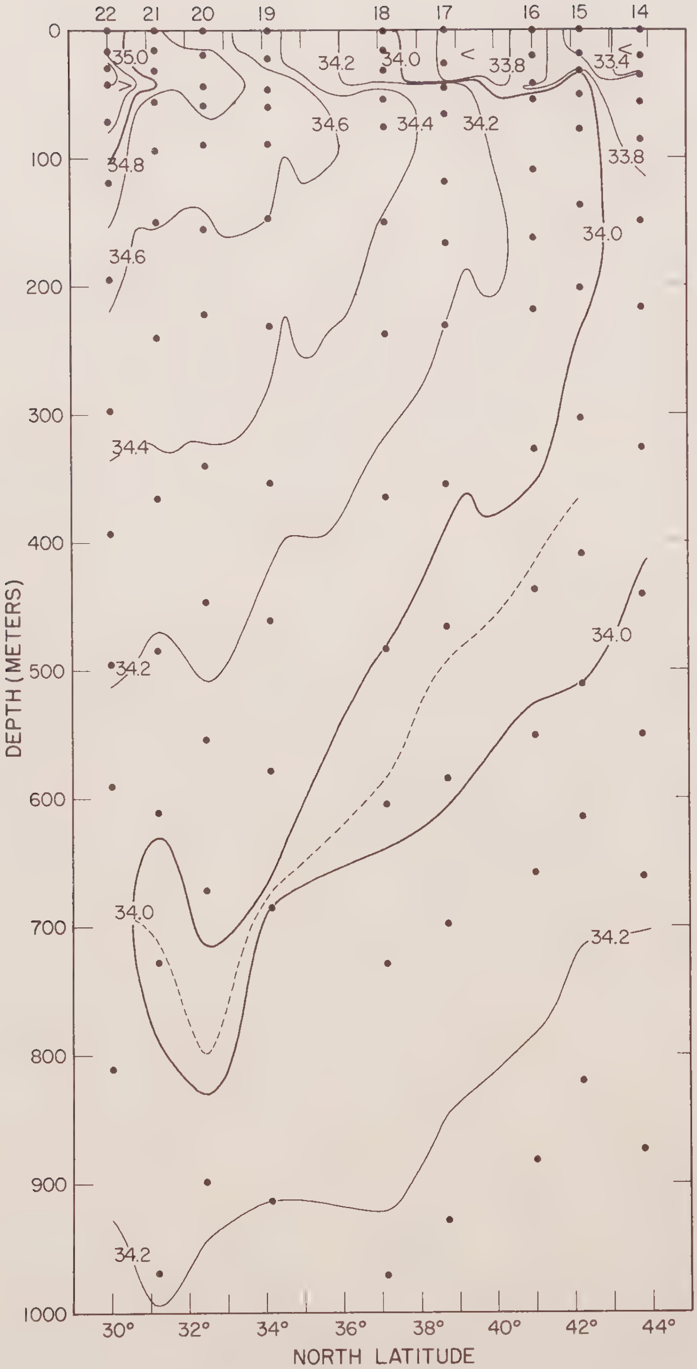


Figure 29.--Vertical section of salinity in parts per thousand along 170° W. longitude; Charles H. Gilbert cruise 17, stations 14-22, September-November 1954. Contour interval 0.2 ‰. Points indicate observed values. Dotted line indicates depth of salinity minima.

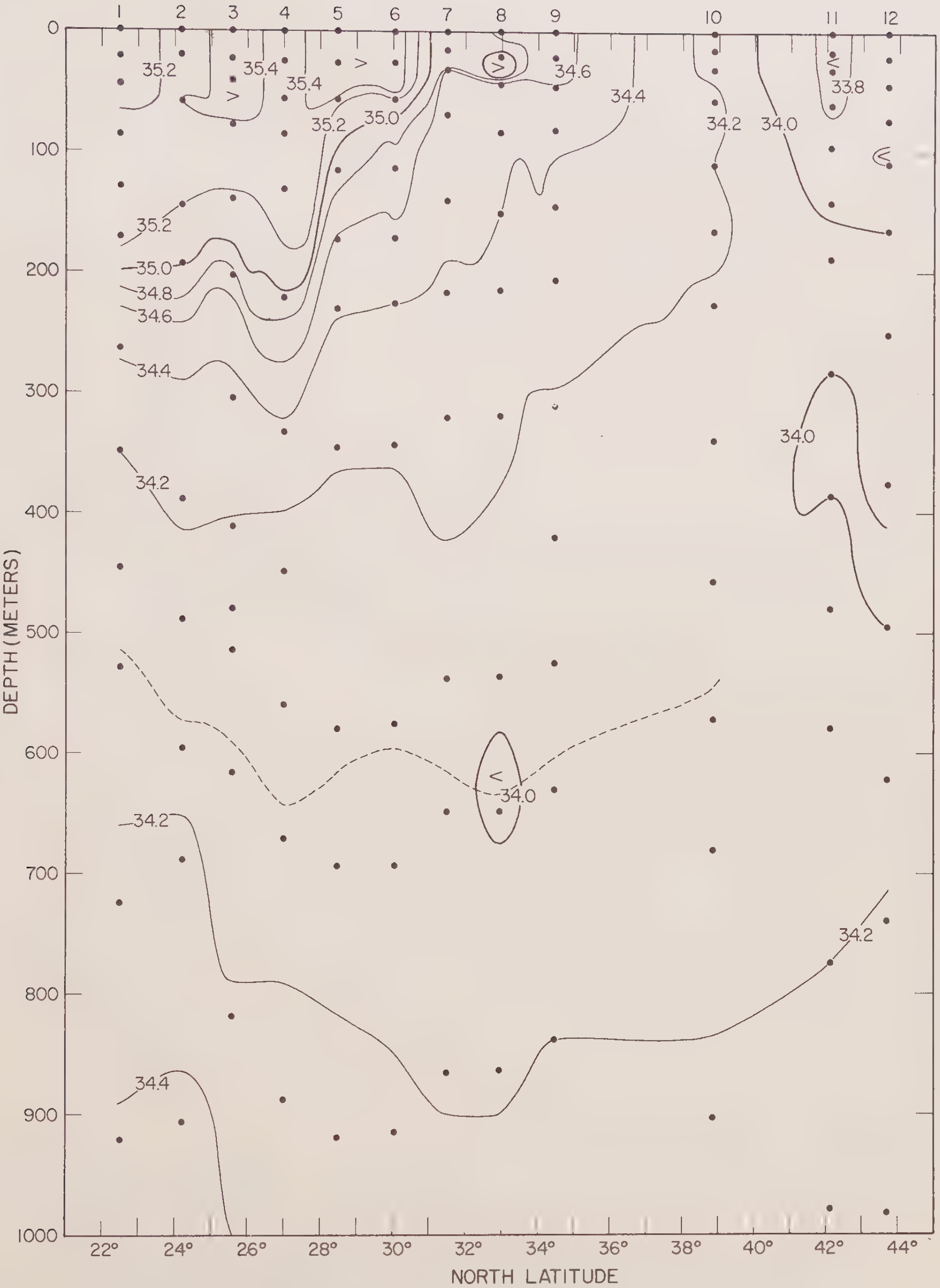


Figure 30.--Vertical section of salinity in parts per thousand along 160°W. longitude; Charles H. Gilbert cruise 17, stations 1-12, September-November 1954. Contour interval 0.2 ‰. Points indicate observed values. Dotted line indicates depth of salinity minima.

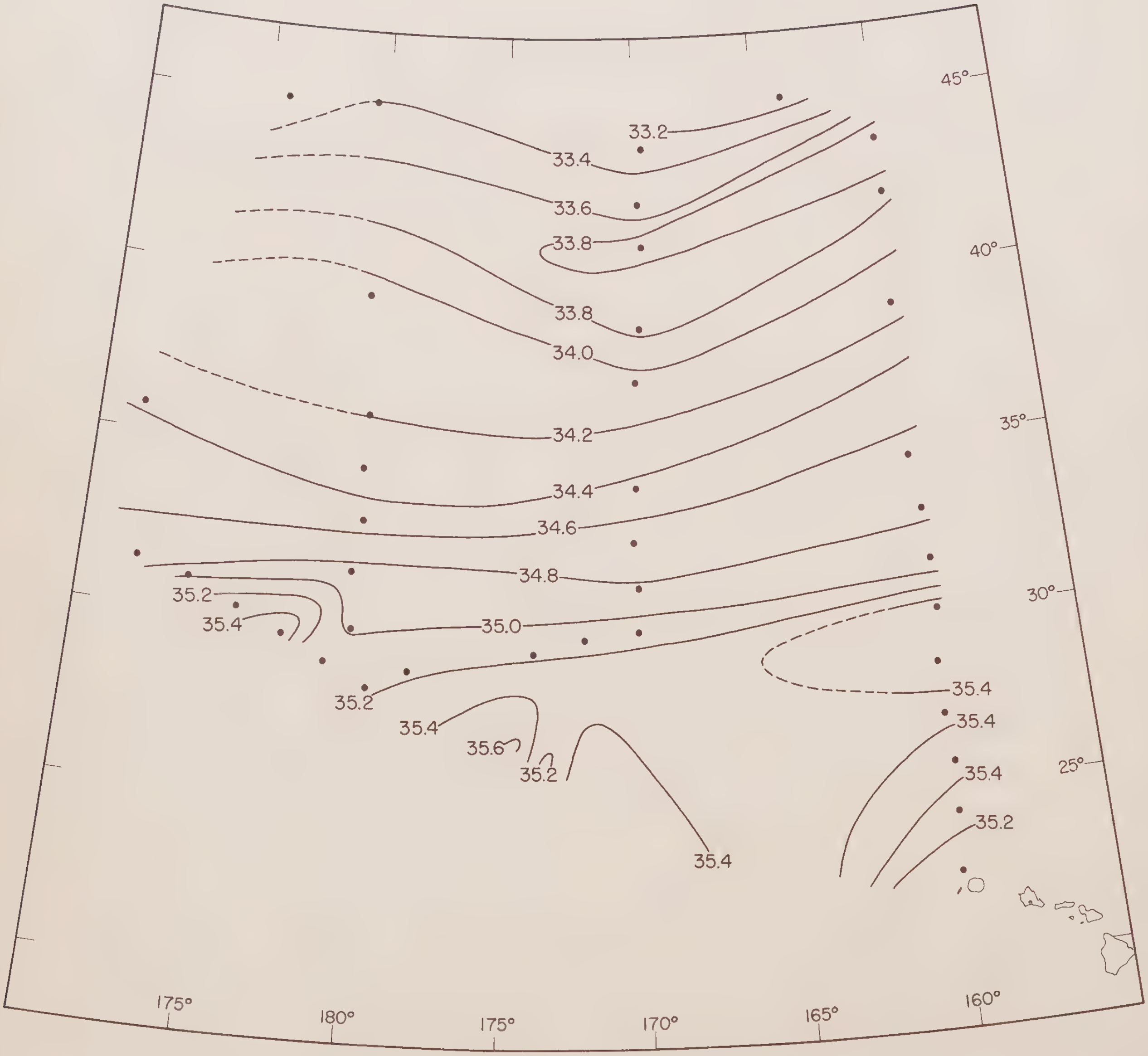

45°
40°
35°
30°
25°
33.2
33.4
33.6
33.8
33.8
34.0
34.2
34.4
34.6
34.8
35.0
35.2
35.4
35.2
35.4
35.6
35.2
35.4
35.4
35.4
35.4
35.2
175°
180°
175°
170°
165°
160°

Figure 31.--Surface salinity in parts per thousand; Charles H. Gilbert cruise 17, September-November 1954. Contour interval 0.2 ‰. Dots indicate observed values.

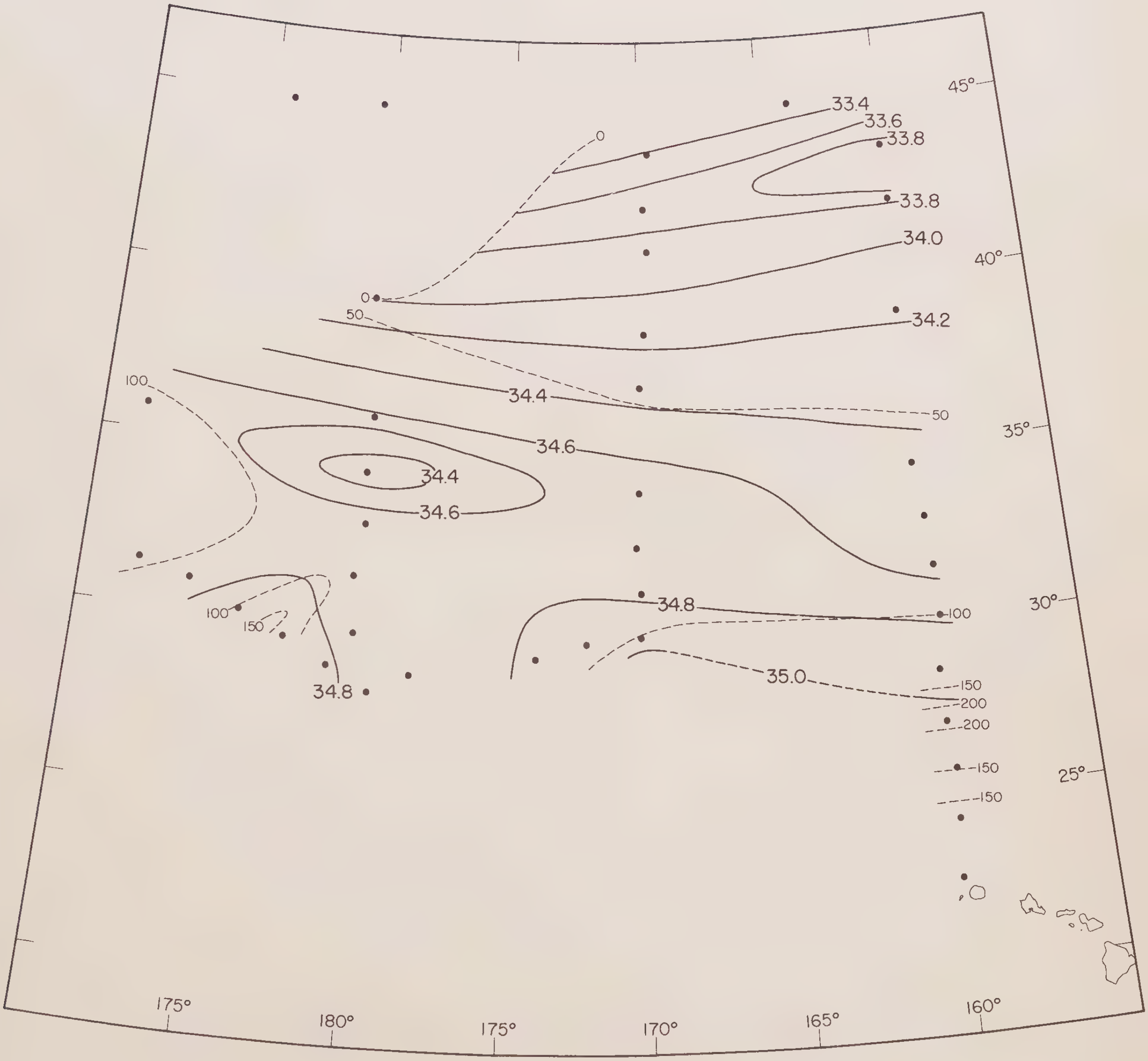

45°
40°
35°
30°
25°
175°
180°
175°
170°
165°
160°
33.4
33.6
33.8
33.8
34.0
34.2
34.4
34.6
34.4
34.6
34.8
34.8
35.0
0
0
50
50
100
100
150
100
150
200
200
150
150

Figure 32.--Salinity in parts per thousand (solid lines) on the 25.2 sigma-t surface (depth in meters, dotted lines); Charles H. Gilbert cruise 17, September-November 1954. Contour intervals: salinity 0.2 ‰, depth of sigma-t surface 50 m. Dots indicate station positions.

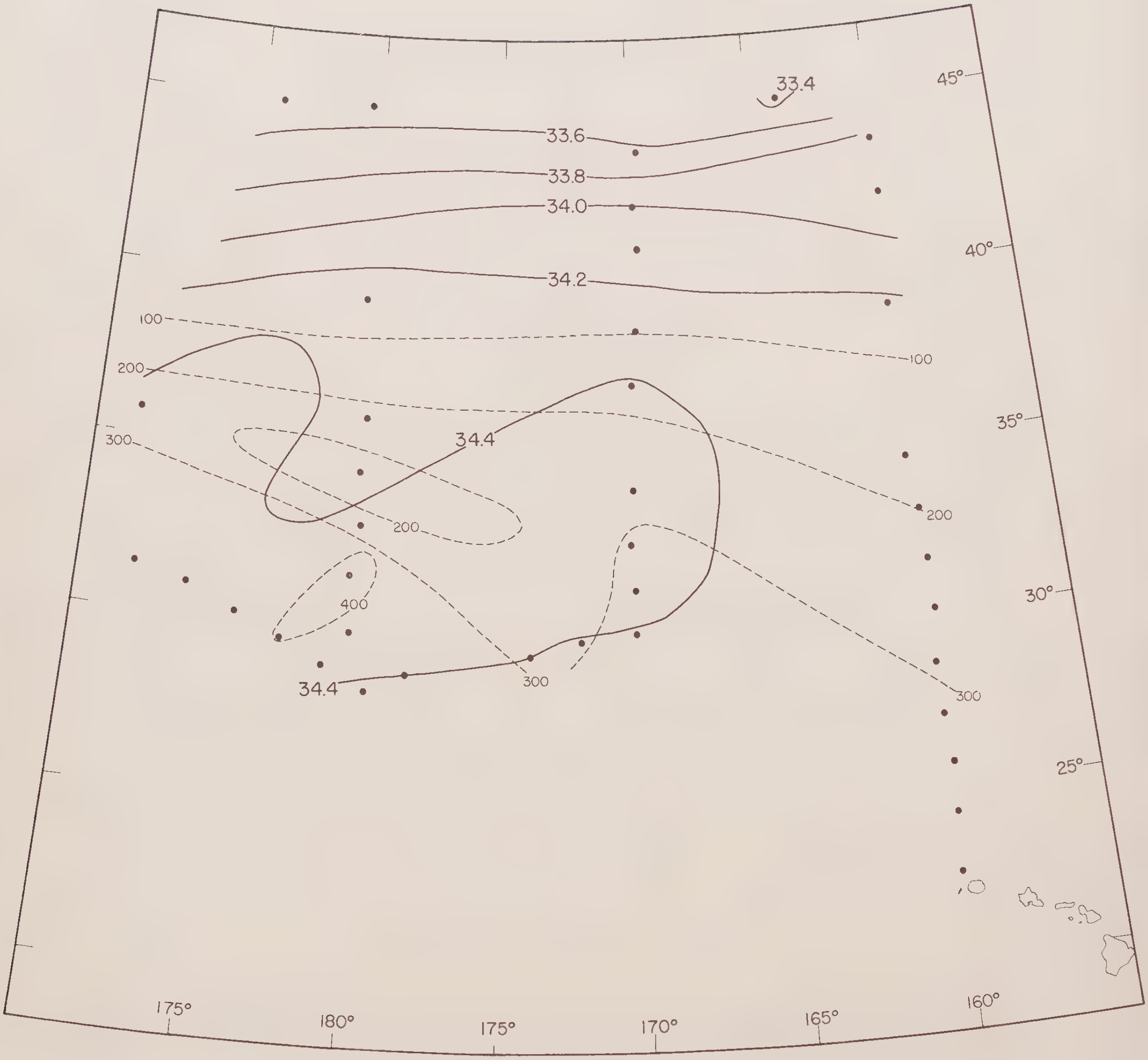

33.4
33.6
33.8
34.0
34.2
34.4
34.4
100
100
200
200
200
300
300
300
400
45°
40°
35°
30°
25°
160°
165°
170°
175°
180°
175°

Figure 33.--Salinity in parts per thousand (solid lines) on the 26.0 sigma-t surface (depth in meters, dotted lines); Charles H. Gilbert cruise 17, September-November 1954. Contour intervals: salinity 0.2 ‰, depth of sigma-t surface 100 m. Dots indicate station positions.

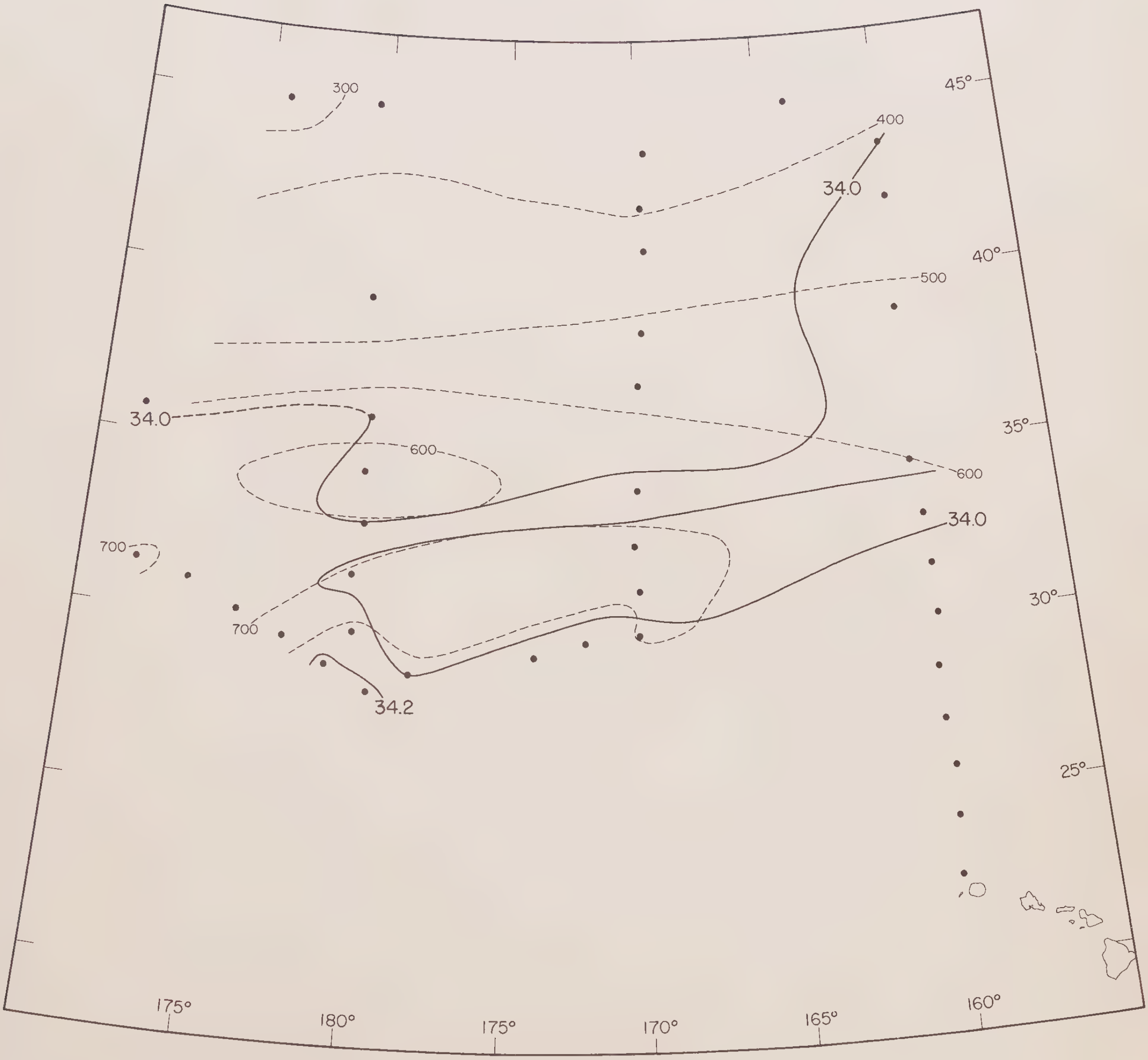

300
400
34.0
45°
40°
500
35°
34.0
600
600
34.0
700
30°
700
34.2
25°
175°
180°
175°
170°
165°
160°

Figure 34.--Salinity in parts per thousand (solid lines) on the 26.8 sigma-t surface (depth in meters, dotted lines); Charles H. Gilbert cruise 17, September-November 1954. Contour intervals: salinity 0.2 ‰, depth of sigma-t surface 100 m. Dots indicate station positions.

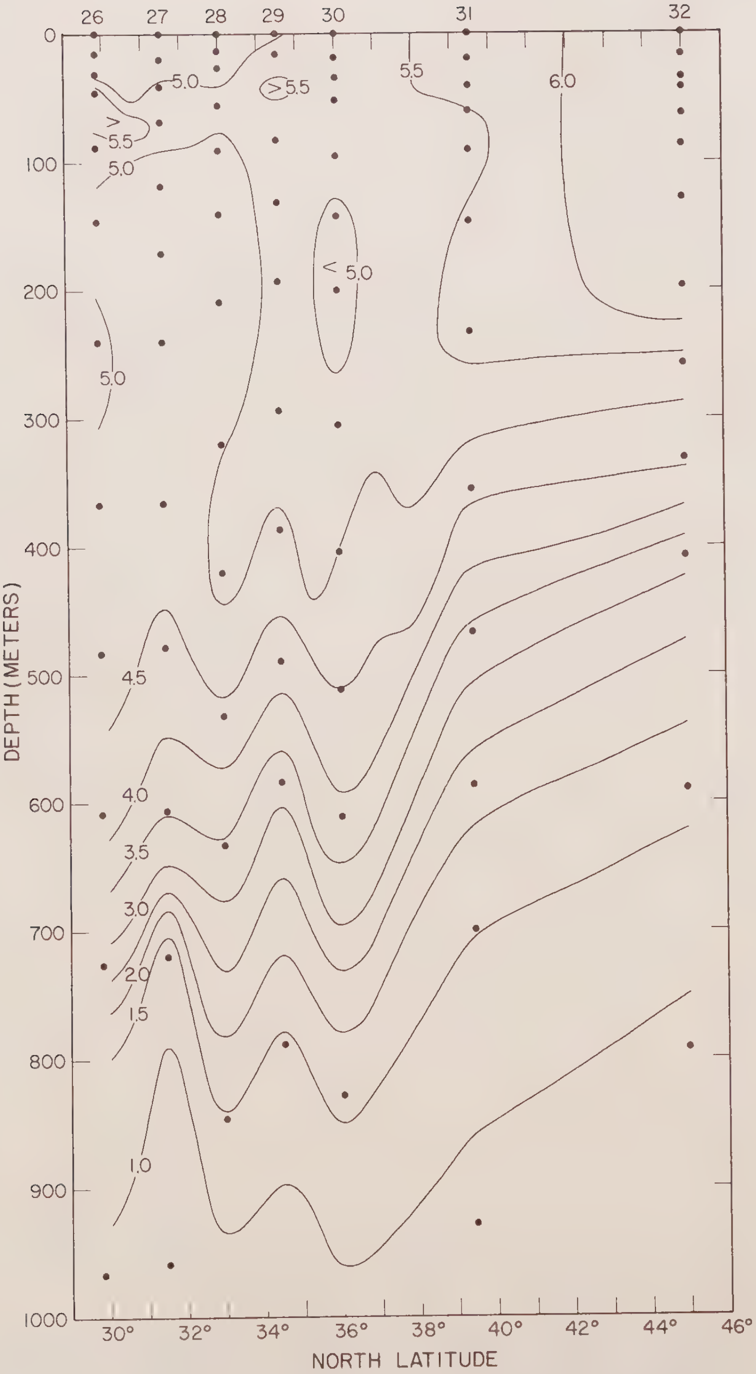


Figure 35.--Vertical section of dissolved oxygen in milliliters per liter along the 180th meridian; Charles H. Gilbert cruise 17, stations 26-32, September- November 1954. Contour interval: 0.5 ml. /l. Points indicate observed values.

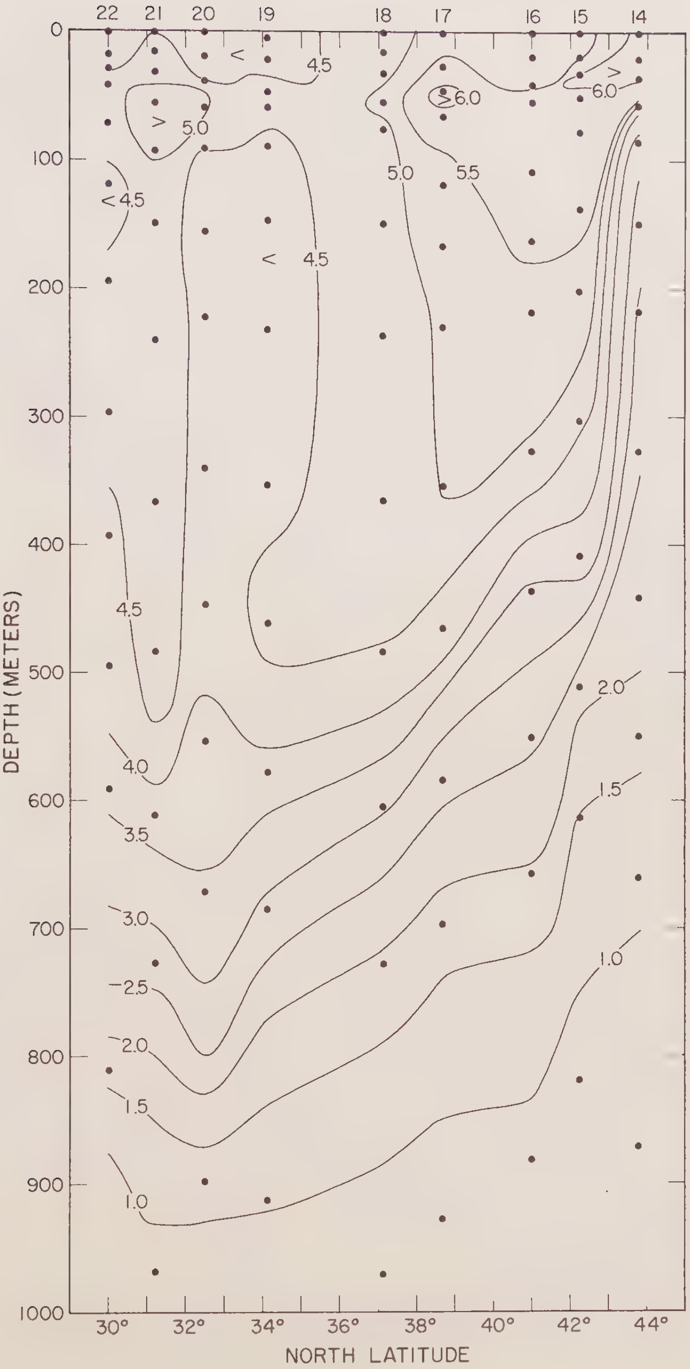


Figure 36.--Vertical section of dissolved oxygen in milliliters per liter along 170°W. longitude; Charles H. Gilbert cruise 17, stations 14-22, September-November 1954. Contour interval: 0.5 ml./l. Points indicate observed values.

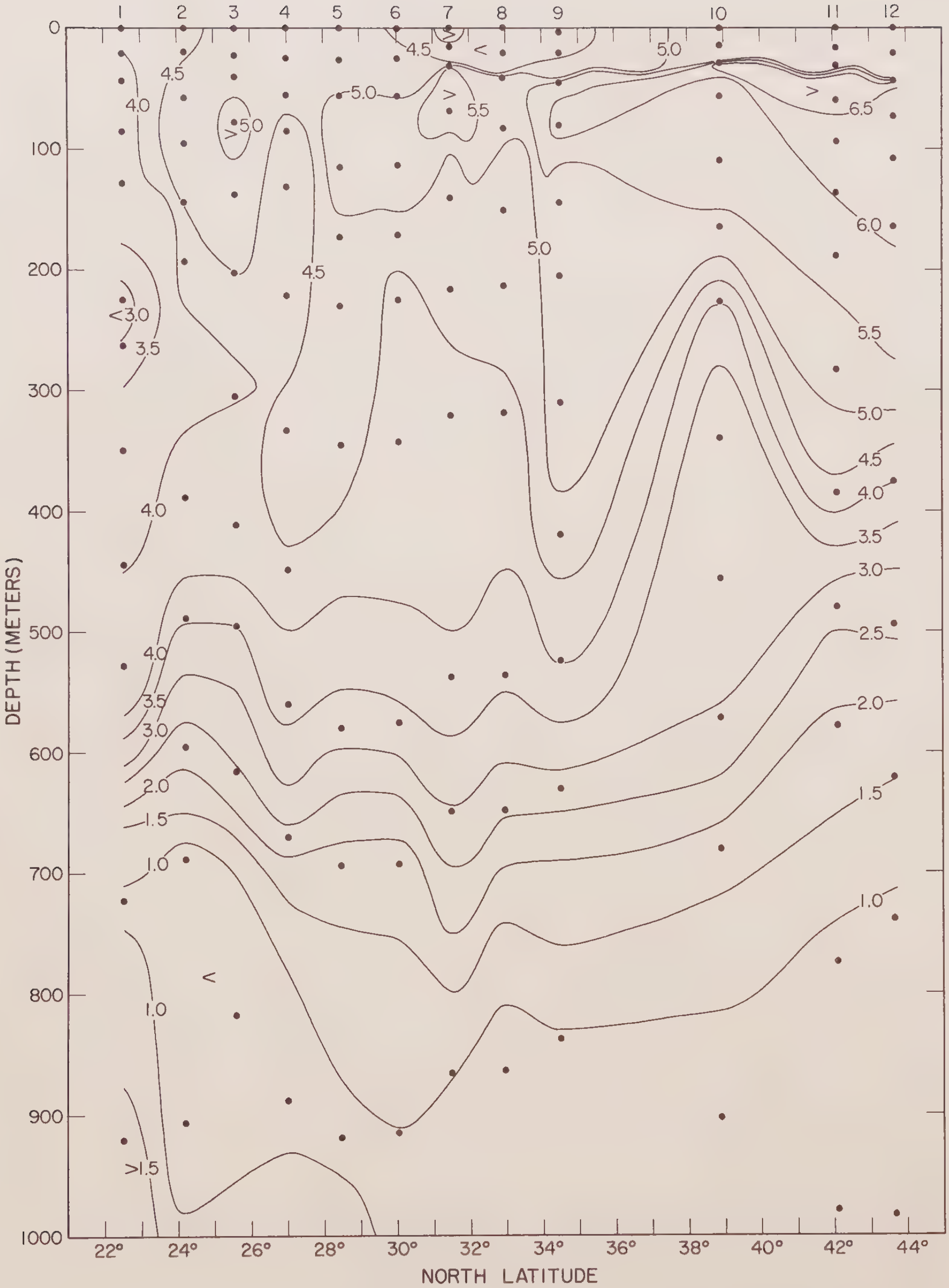


Figure 37.--Vertical section of dissolved oxygen in milliliters per liter along 160°W. longitude; Charles H. Gilbert cruise 17, stations 1-12, September-November 1954. Contour interval: 0.5 ml./l. Points indicate observed values.

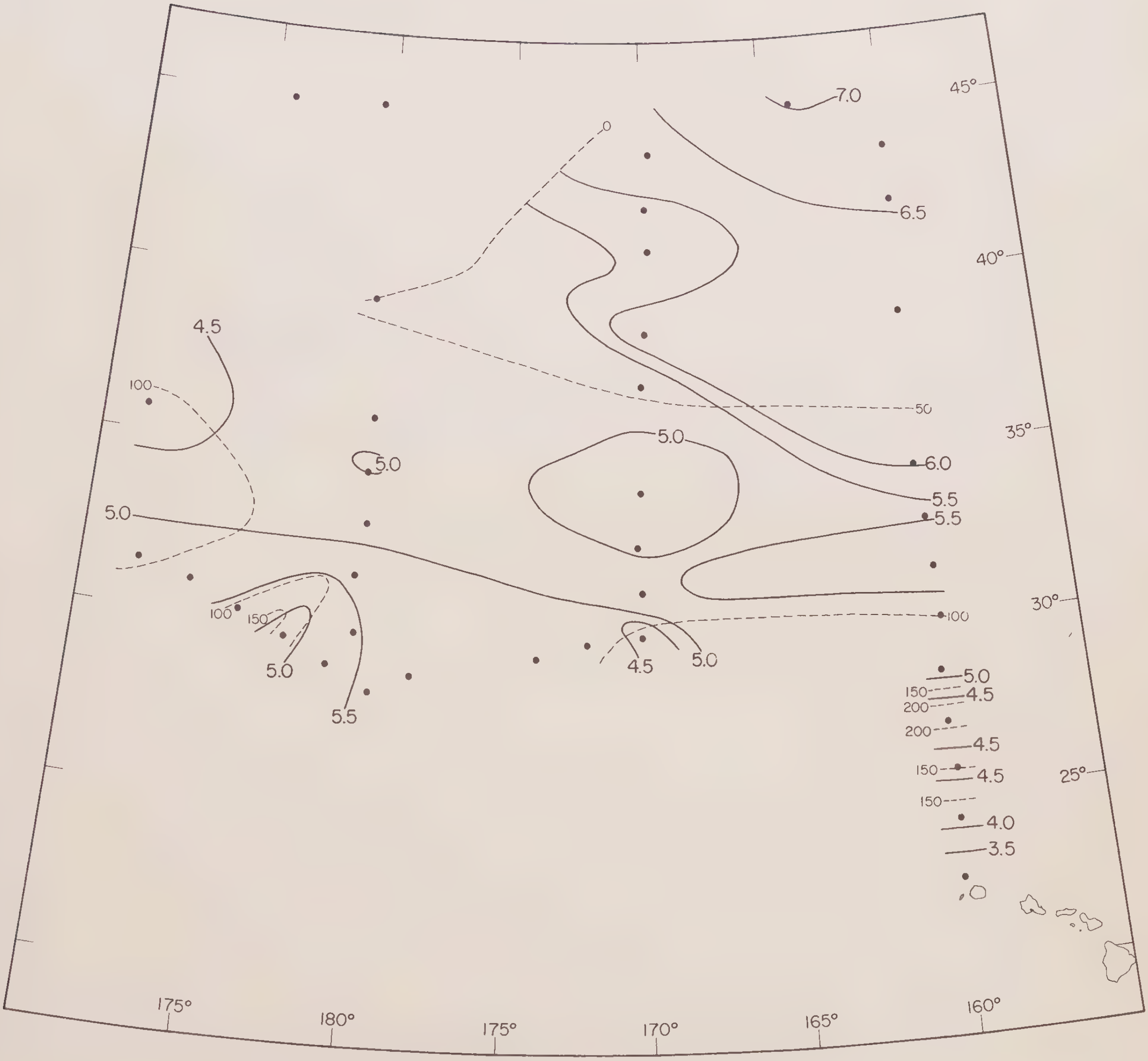

7.0
45°
0
6.5
40°
4.5
100
50
35°
5.0
5.0
6.0
5.5
5.0
5.5
30°
100
100
150
5.0
4.5
5.0
5.5
5.0
150
4.5
200
200
4.5
150
4.5
25°
150
4.0
3.5
175°
180°
175°
170°
165°
160°

Figure 38.--Dissolved oxygen in milliliters per liter (solid lines) on the 25.2 sigma-t surface (depths in meters, dotted lines); Charles H. Gilbert cruise 17, September-November 1954. Contour intervals: dissolved oxygen 0.5 ml./l., depth of sigma-t surface 50 m. Dots indicate station positions.

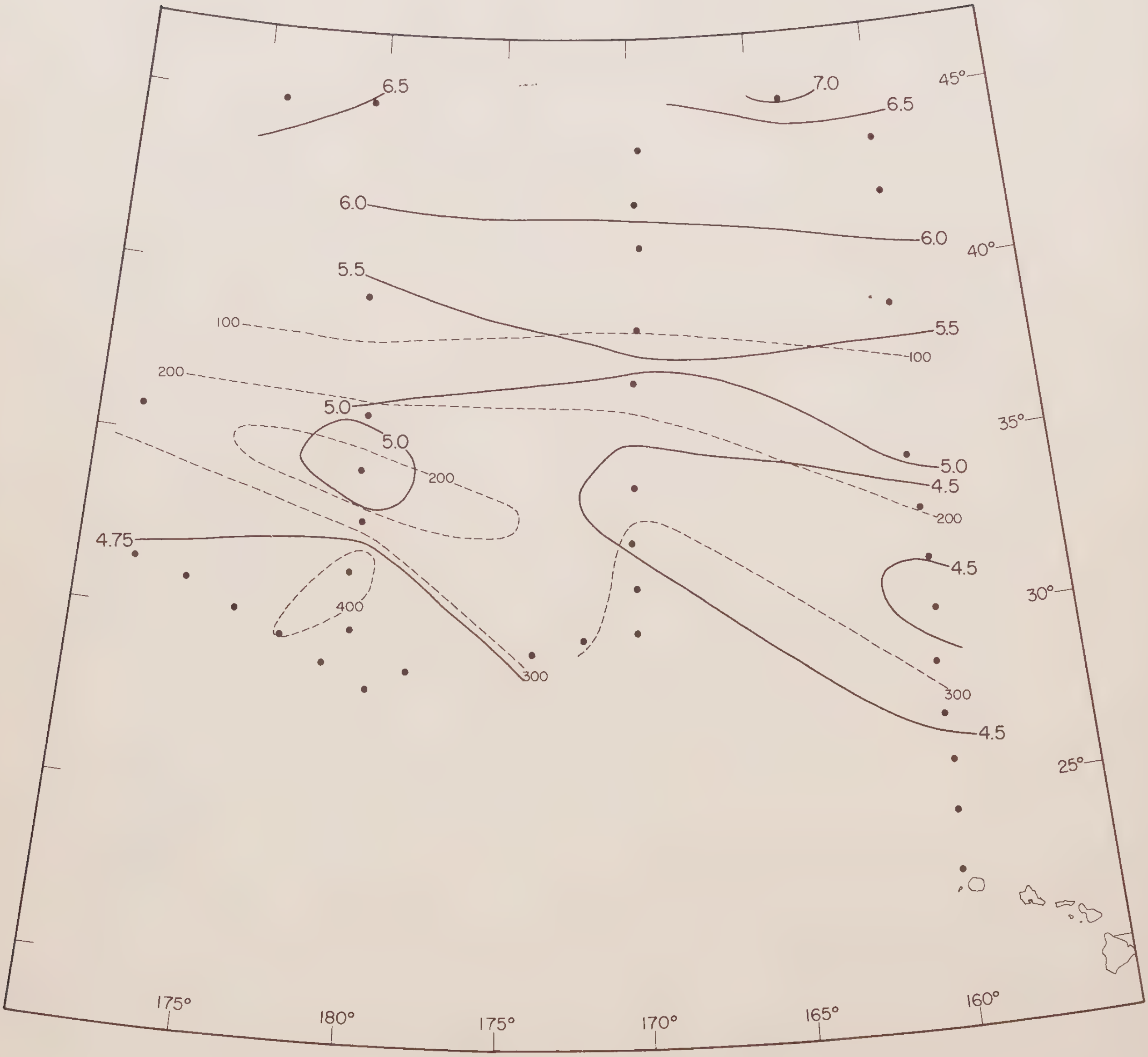

6.5
7.0
6.5
45°
6.0
6.0
40°
5.5
100
5.5
100
200
5.0
5.0
200
35°
5.0
4.5
200
4.75
4.5
400
30°
300
300
4.5
25°
175°
180°
175°
170°
165°
160°

Figure 39.--Dissolved oxygen in milliliters per liter (solid lines) on the 26.0 sigma-t surface (depth in meters, dotted lines); Charles H. Gilbert cruise 17, September-November 1954. Contour intervals: dissolved oxygen 0.5 ml./l., depth of sigma-t surface 100 m. Dots indicate station positions.

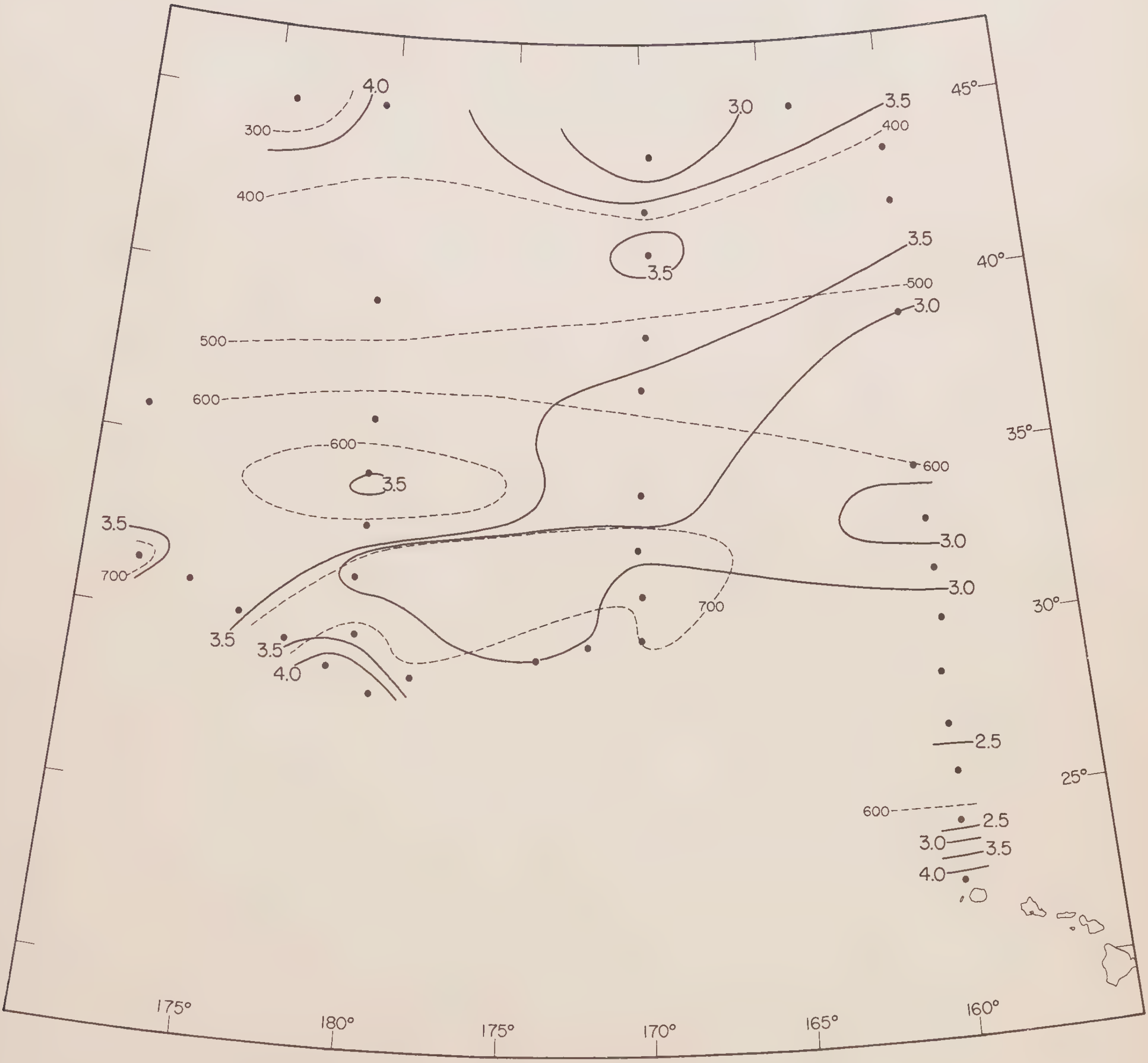

4.0
300
400
3.0
3.5
400
45°
3.5
3.5
40°
500
3.0
500
600
35°
600
600
3.5
3.5
700
3.0
3.0
700
30°
3.5
3.5
4.0
2.5
25°
600
2.5
3.0
3.5
4.0
175°
180°
175°
170°
165°
160°

Figure 40. --Dissolved oxygen in milliliters per liter (solid lines) on the 26.8 sigma-t surface (depth in meters, dotted lines); Charles H. Gilbert cruise 17, September-November 1954. Contour intervals: dissolved oxygen 0.5 ml. /l., depth of sigma-t surface 100 m. Dots indicate station positions.

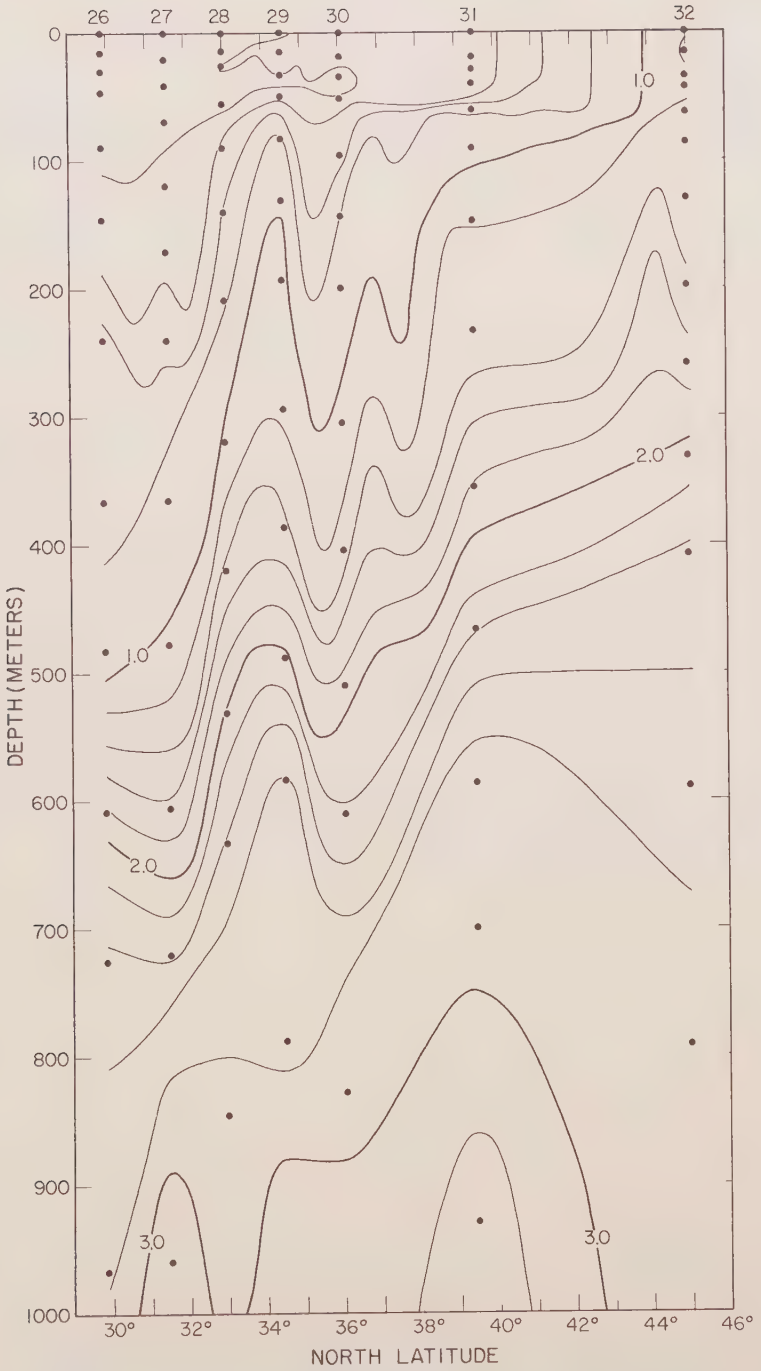


Figure 41.--Vertical section of inorganic phosphate in microgram-atoms per liter along the 180th meridian; Charles H. Gilbert cruise 17, stations 26-32, September-November 1954. Contour interval 0.2 µg at./l.

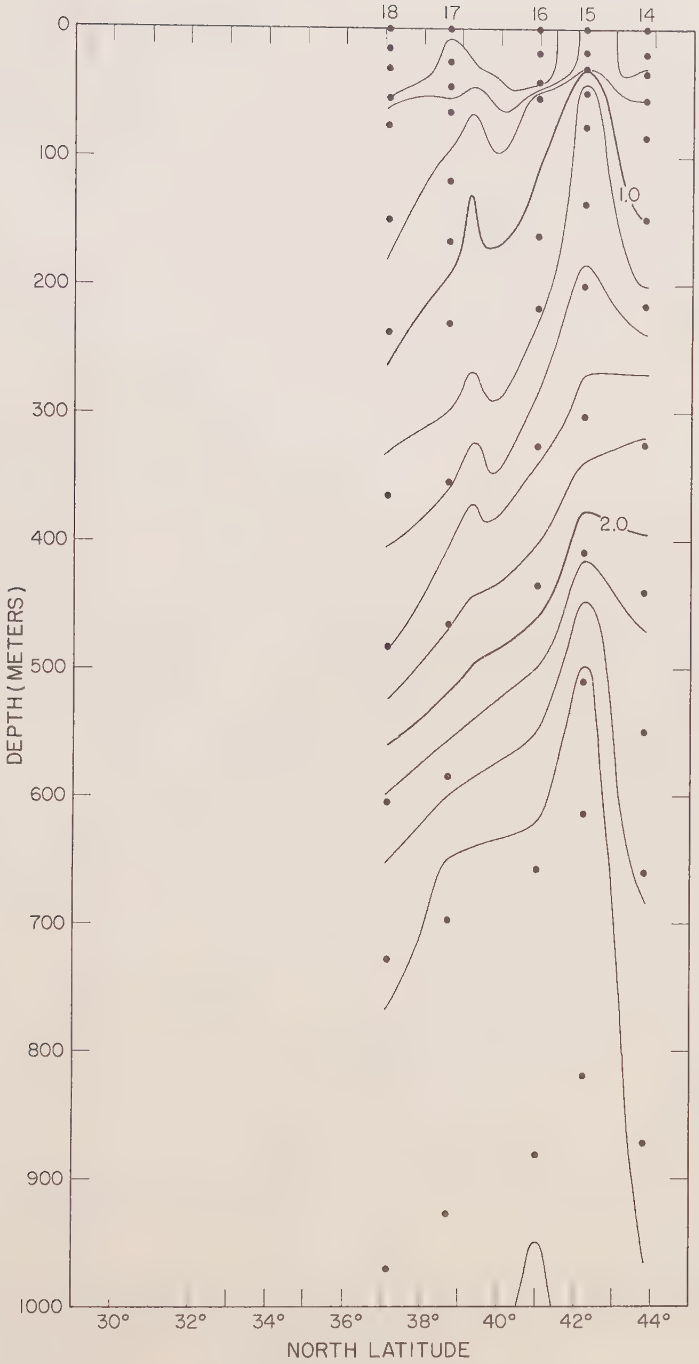


Figure 42.--Vertical section of inorganic phosphate in microgram-atoms per liter along 170°W. longitude; Charles H. Gilbert cruise 17, stations 14-18, September-November 1954. Contour interval 0.2 µg at./l.

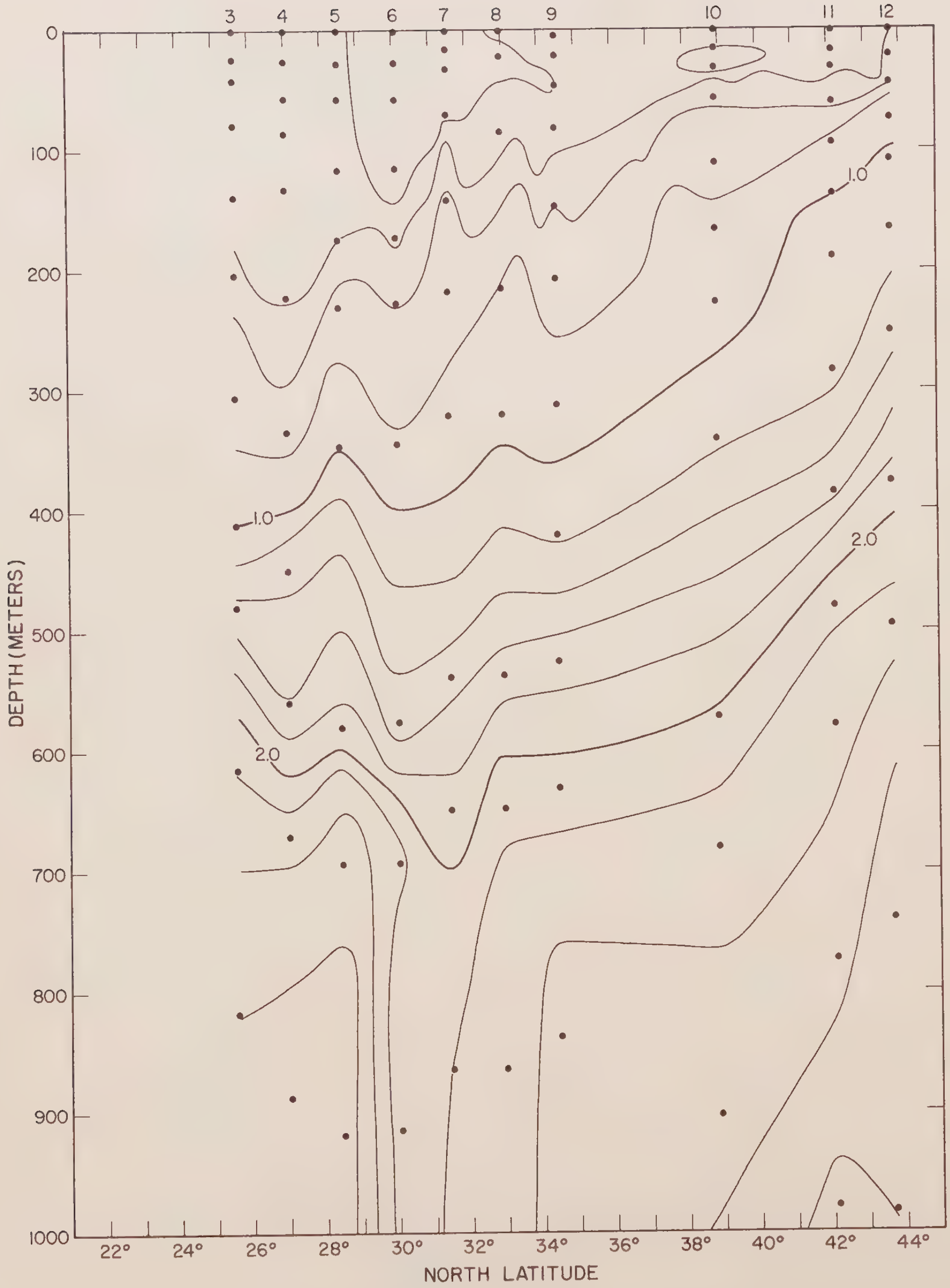


Figure 43.--Vertical section of inorganic phosphate in microgram-atoms per liter along 160 °W. longitude; Charles H. Gilbert cruise 17, stations 3-12, September-November 1954. Contour interval 0.2 µg at./l.

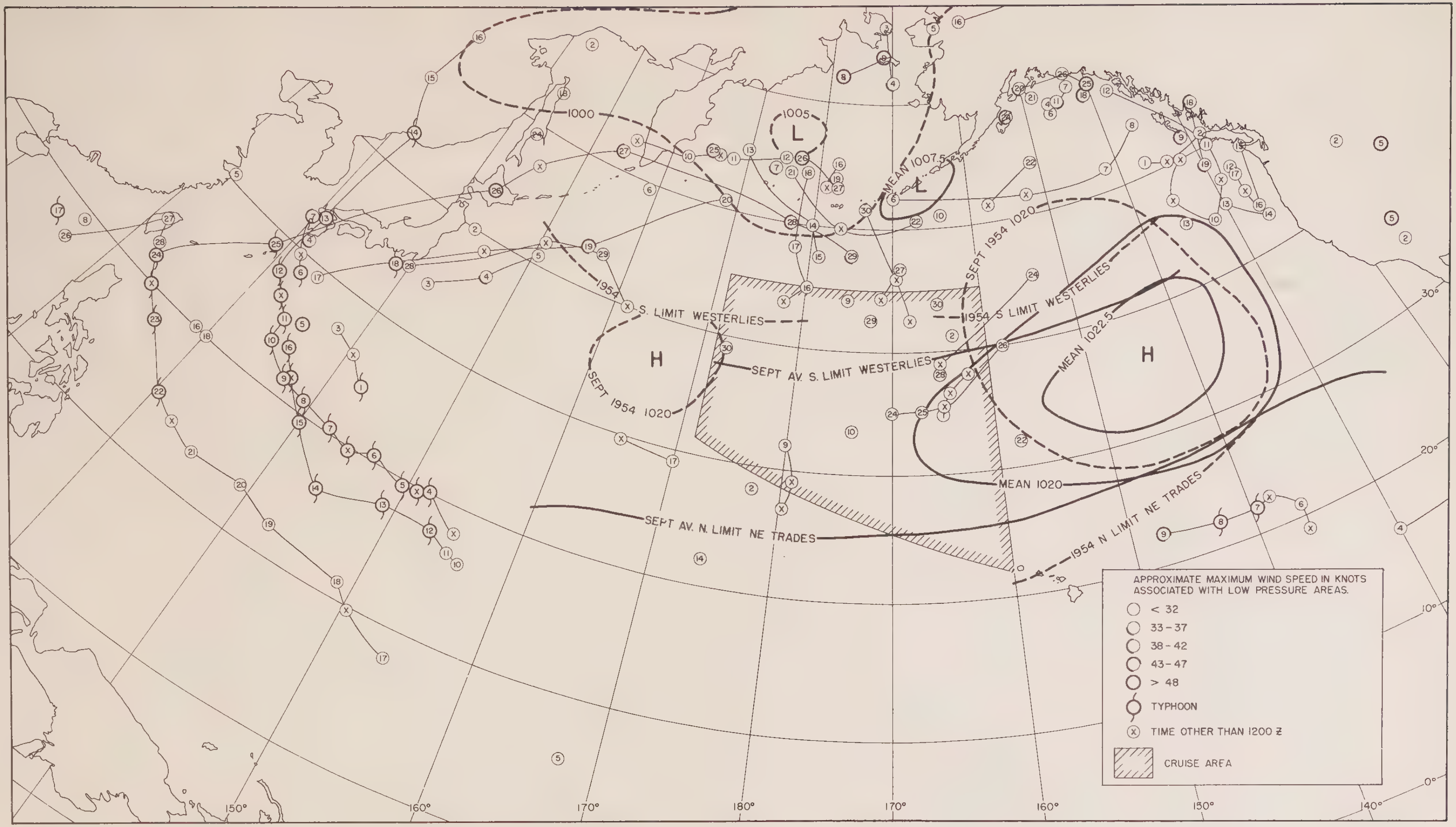

1000
1005
L
MEAN 1007.5
L
SEPT 1954 1020
1954 S LIMIT WESTERLIES
MEAN 1022.5
H
1954 S. LIMIT WESTERLIES
H
SEPT 1954 1020
SEPT AV. S. LIMIT WESTERLIES
MEAN 1020
SEPT AV. N. LIMIT NE TRADES
1954 N LIMIT NE TRADES
APPROXIMATE MAXIMUM WIND SPEED IN KNOTS ASSOCIATED WITH LOW PRESSURE AREAS.
< 32
33 - 37
38 - 42
43 - 47
> 48
TYPHOON
TIME OTHER THAN 1200 Z
CRUISE AREA
150°
160°
170°
180°
170°
160°
150°
140°
0°
10°
20°
30°

Figure 44.--Normal (heavy solid lines) and mean September 1954 (broken lines) position of the Aleutian Low and Eastern North Pacific High; normal and 1954 mean monthly limits of the northeast trades and westerlies; tracks of centers of low pressure areas, showing daily positions.

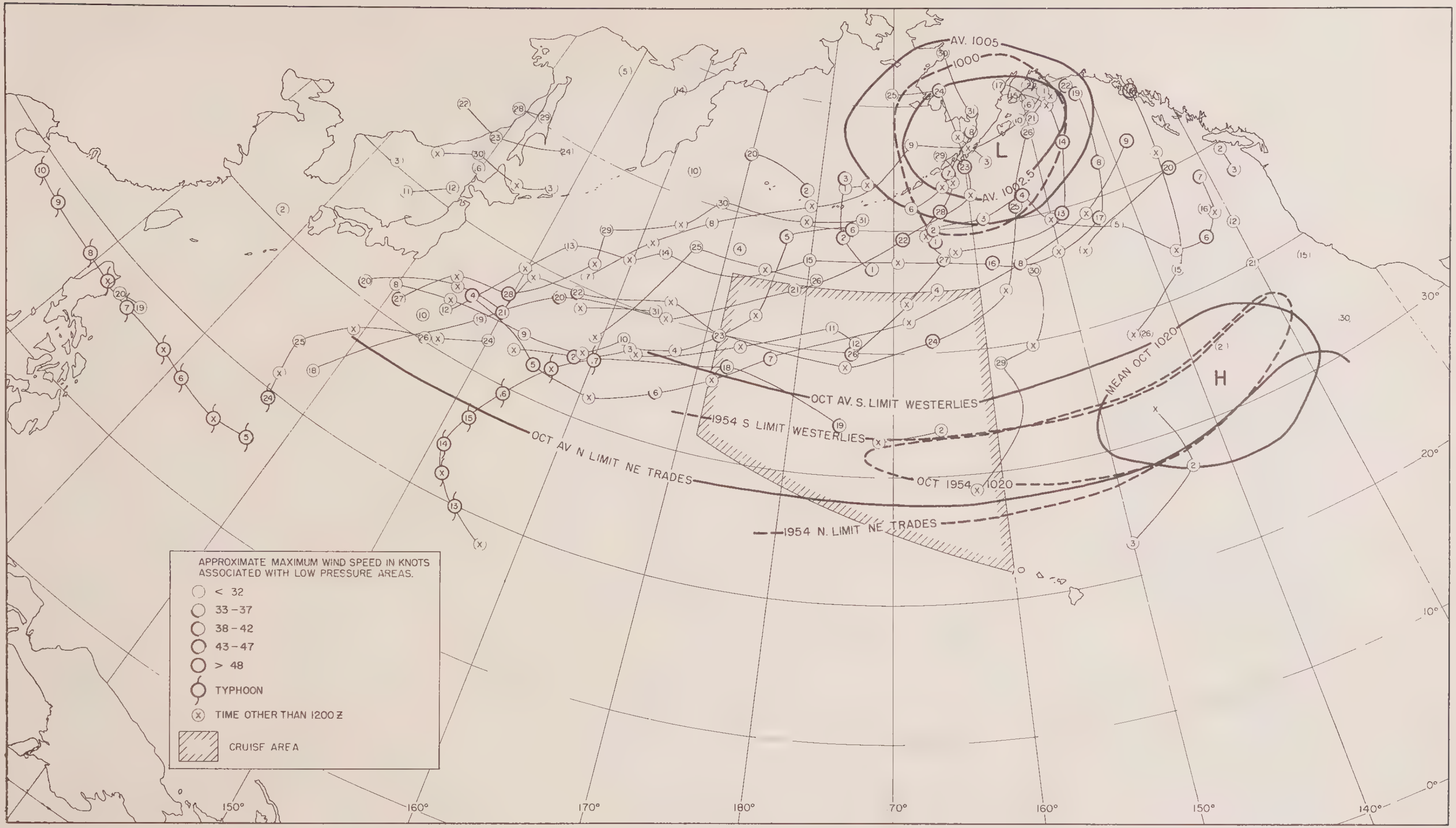

AV. 1005
1000
L
AV. 1002.5
H
MEAN OCT 1020
OCT AV. S. LIMIT WESTERLIES
1954 S LIMIT WESTERLIES
OCT 1954 1020
OCT AV N LIMIT NE TRADES
1954 N. LIMIT NE TRADES
APPROXIMATE MAXIMUM WIND SPEED IN KNOTS ASSOCIATED WITH LOW PRESSURE AREAS.
< 32
33 - 37
38 - 42
43 - 47
> 48
TYPHOON
TIME OTHER THAN 1200 Z
CRUISF AREA
150°
160°
170°
180°
70°
160°
150°
140°
30°
20°
10°
0°

Figure 45. --Normal (heavy solid lines) and mean October 1954 (broken lines) position of the Aleutian Low and Eastern North Pacific High; normal and 1954 mean monthly limits of the northeast trades and westerlies; tracks of centers of low pressure areas, showing daily positions.

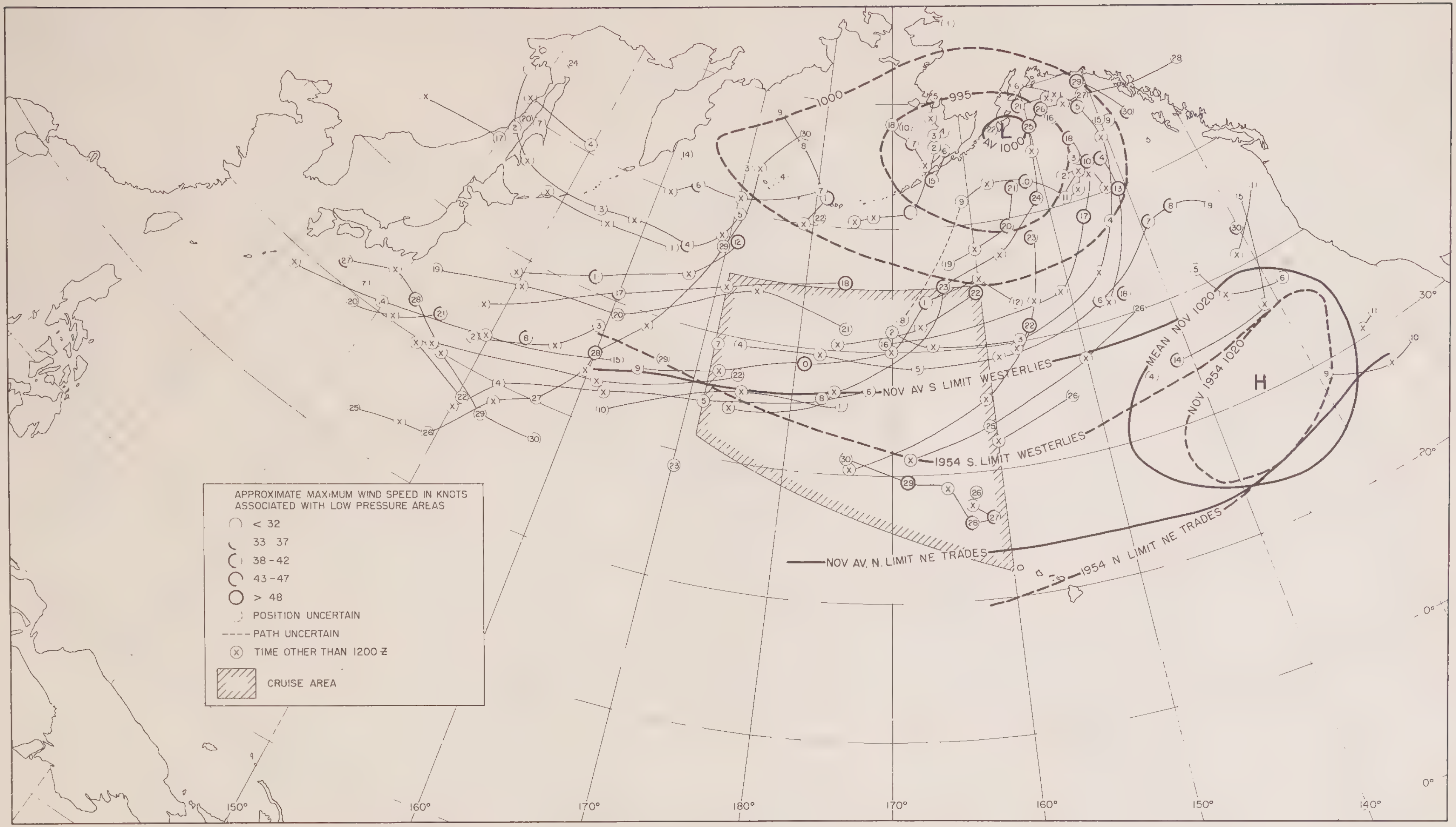

APPROXIMATE MAXIMUM WIND SPEED IN KNOTS ASSOCIATED WITH LOW PRESSURE AREAS
< 32
33 37
38 - 42
43 - 47
> 48
POSITION UNCERTAIN
PATH UNCERTAIN
TIME OTHER THAN 1200 Z
CRUISE AREA
L
AV 1000
995
1000
H
MEAN NOV 1020
NOV 1954 1020
NOV AV S LIMIT WESTERLIES
1954 S. LIMIT WESTERLIES
NOV AV. N. LIMIT NE TRADES
1954 N LIMIT NE TRADES
150°
160°
170°
180°
170°
160°
150°
140°
30°
20°
0°
0°

Figure 46.--Normal (heavy solid lines) and mean November 1954 (broken lines) position of the Aleutian Low and Eastern North Pacific High; normal and 1954 mean monthly limits of the northeast trades and westerlies; tracks of centers of low pressure areas, showing daily positions.

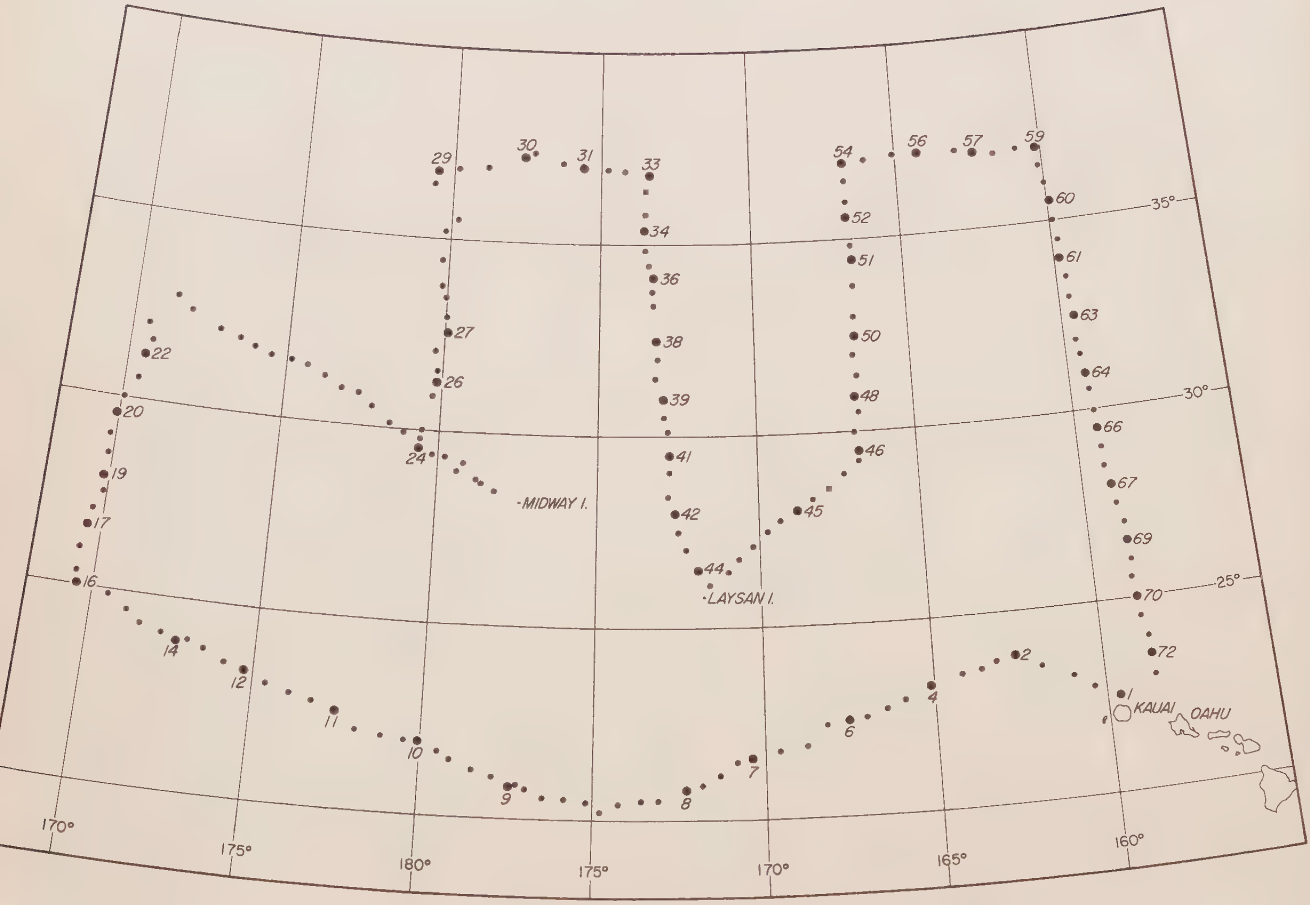
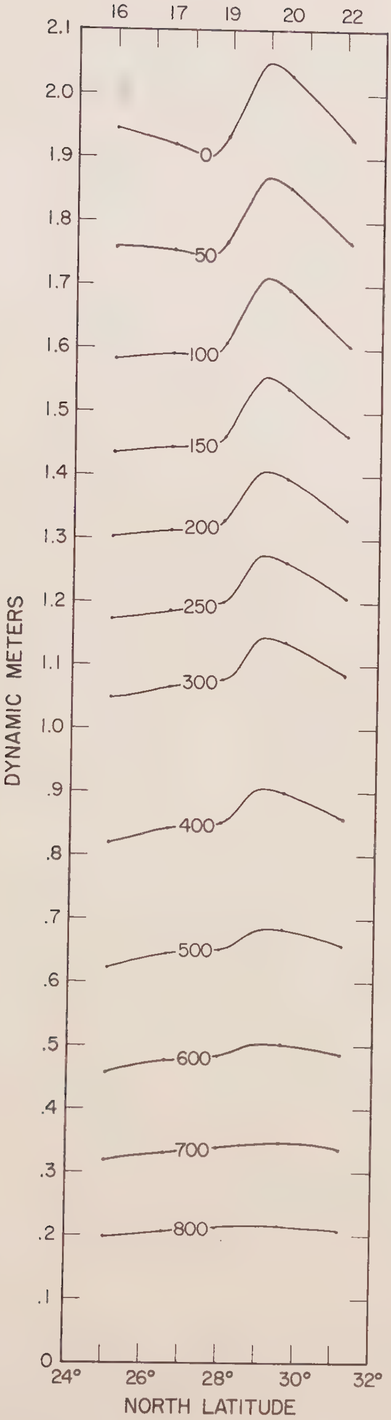

29
30
31
33
54
56
57
59
60
52
34
51
61
36
63
27
38
50
22
26
64
39
48
20
66
46
24
41
19
67
MIDWAY I.
45
42
17
69
44
LAYSAN I.
16
70
14
2
72
12
4
1
KAUAI
OAHU
11
6
10
7
9
8
35°
30°
25°
170°
175°
180°
175°
170°
165°
160°

Figure 47.--Oceanographic station positions, Hugh M. Smith cruise 27, January-February 1955. Large numbered dots indicate oceanographic stations. Small dots indicate positions of BT lowerings between stations.



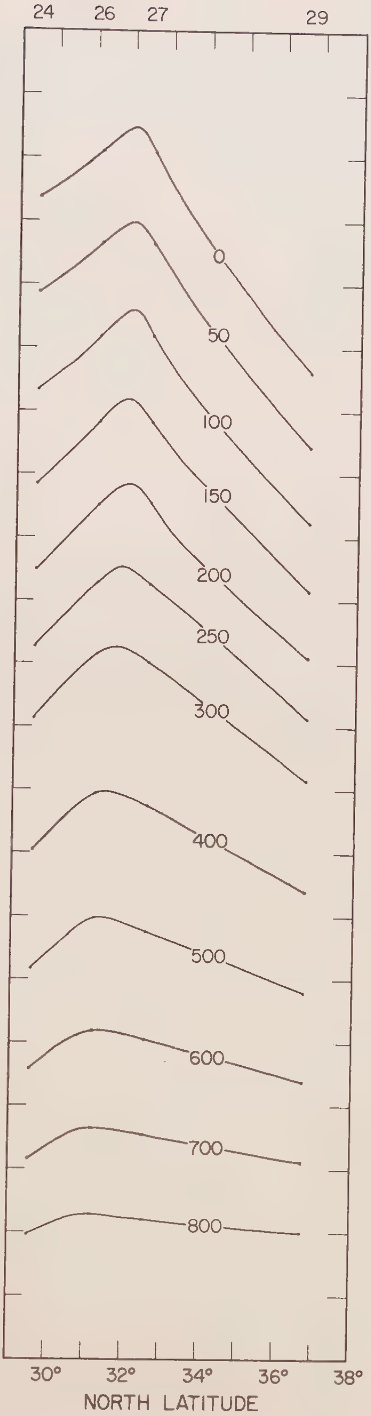
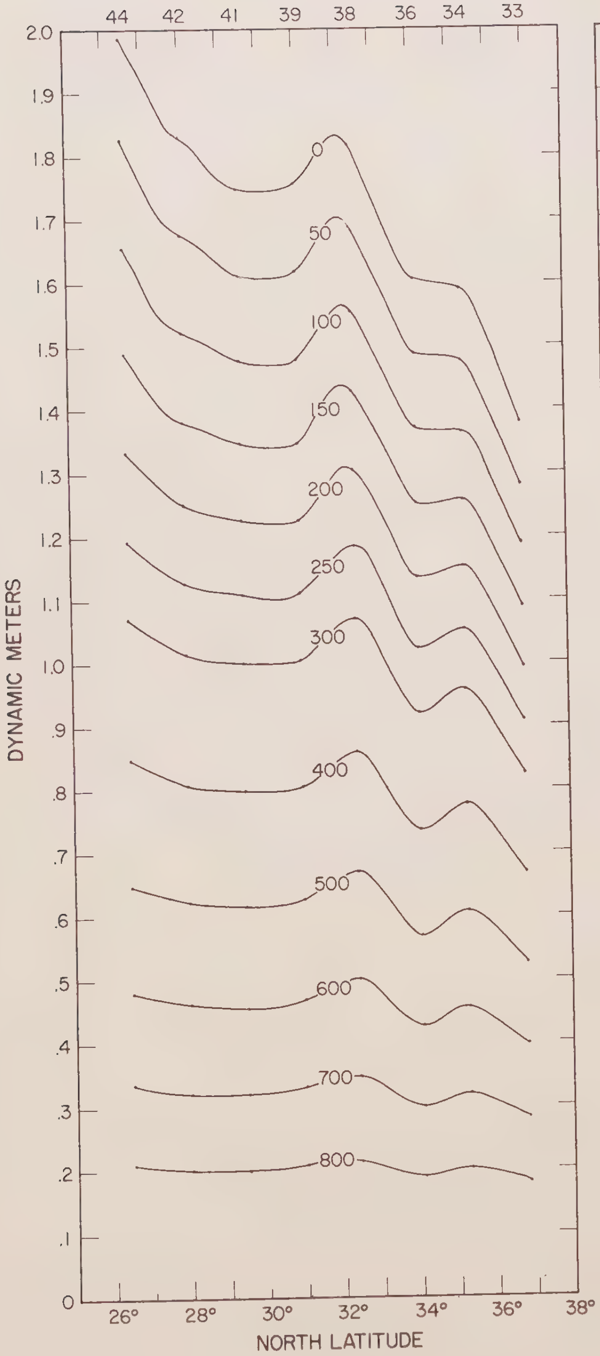


Figure 48.--Smoothed geopotential anomaly of the isobaric surfaces in dynamic meters relative to the 1,000-db. surface along 170°E. longitude; *Hugh M. Smith* cruise 27, stations 16-22, January-February 1955. Points represent computed values.

Figure 49.--Same along the 180th meridian, stations 24-29.



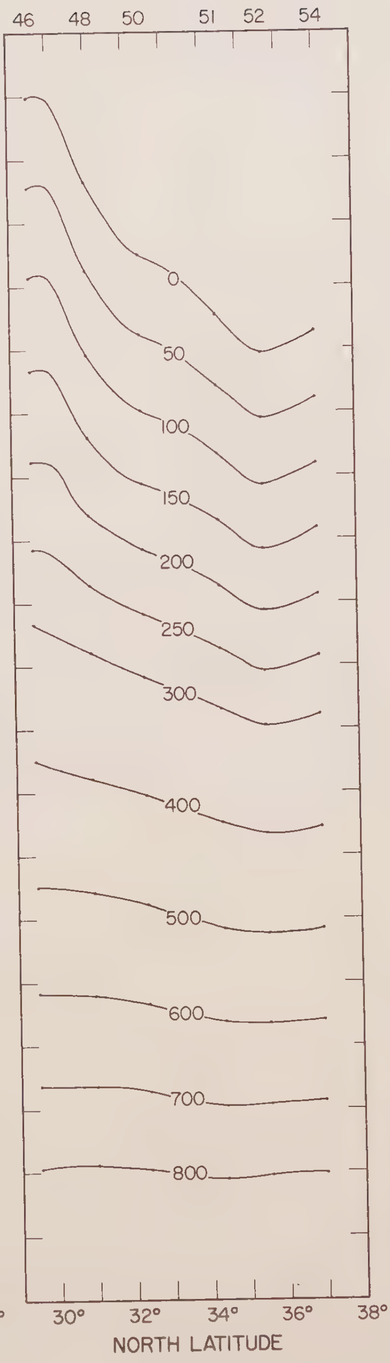


Figure 50.--Smoothed geopotential anomaly of the isobaric surfaces in dynamic meters relative to the 1,000-db. surface along 172°W. longitude; Hugh M. Smith cruise 27, stations 33-44, January-February 1955. Points represent computed values.

Figure 51.--Same along 167°W. longitude, stations 46-54.

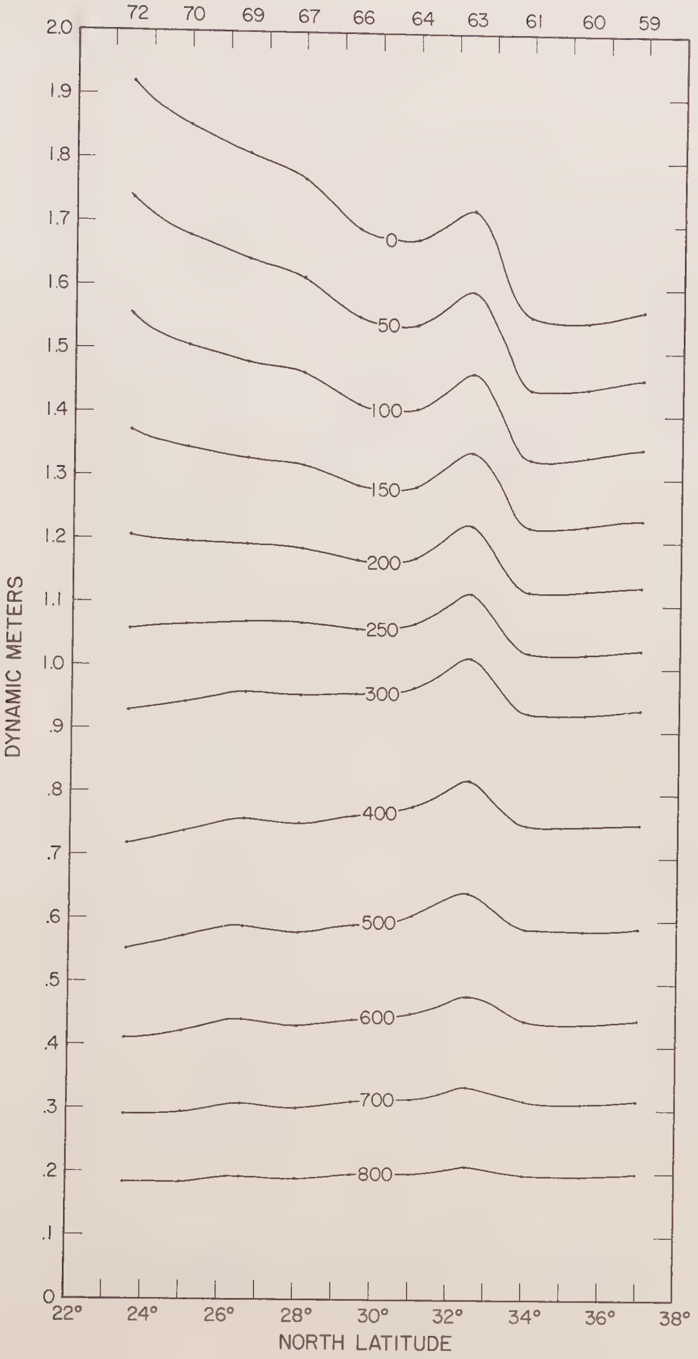
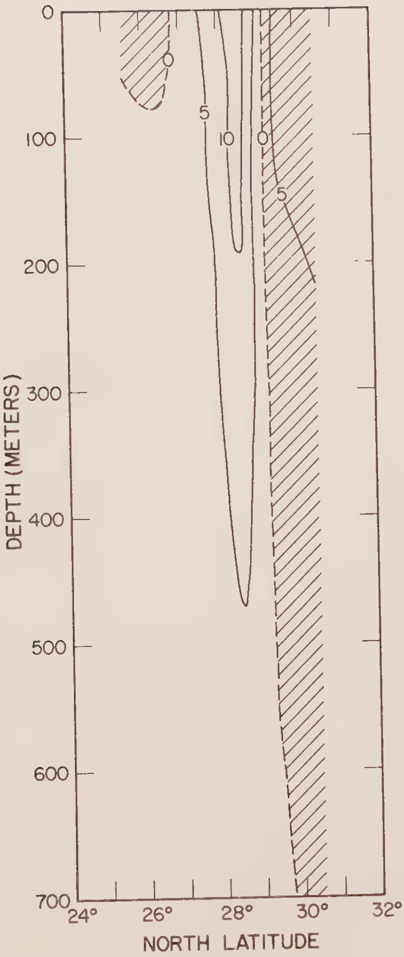


Figure 52.--Smoothed geopotential anomaly of the isobaric surfaces in dynamic meters relative to the 1,000-db. surface along 159°W. longitude; Hugh M. Smith cruise 27, stations 59-72, January-February 1955. Points represent computed values.



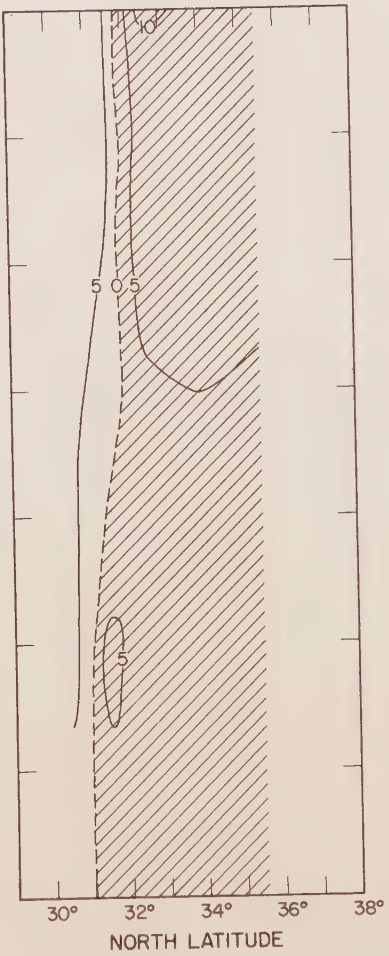
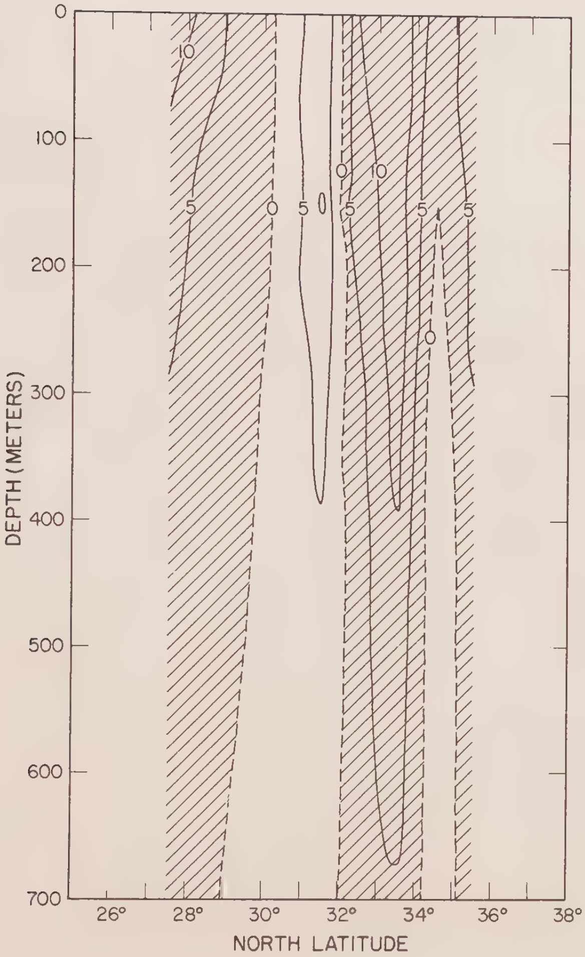


Figure 53.--Zonal components of the geostrophic currents in centimeters per second across 170°E. longitude; Hugh M. Smith cruise 27, January-February 1955. Hatched areas indicate easterly flow. Contour interval 5 cm./sec.

Figure 54.--Same across the 180th meridian.



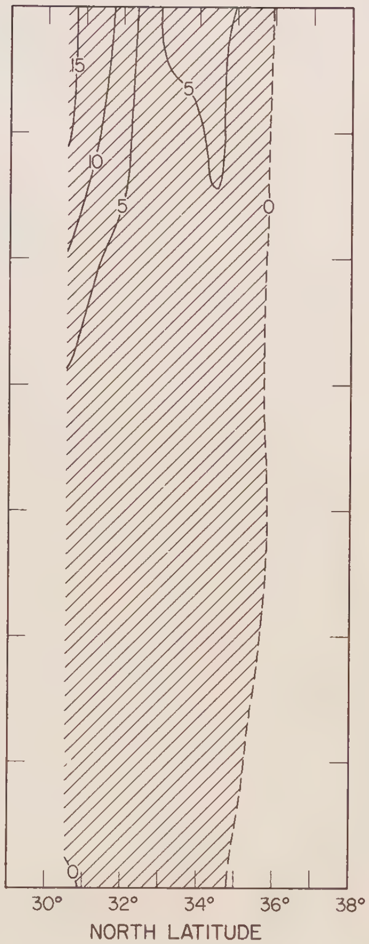


Figure 55.--Zonal components of the geostrophic currents in centimeters per second across 172°W. longitude; Hugh M. Smith cruise 27, January-February 1955. Hatched areas indicate easterly flow. Contour interval 5 cm./sec.

Figure 56.--Same across 167°W. longitude.

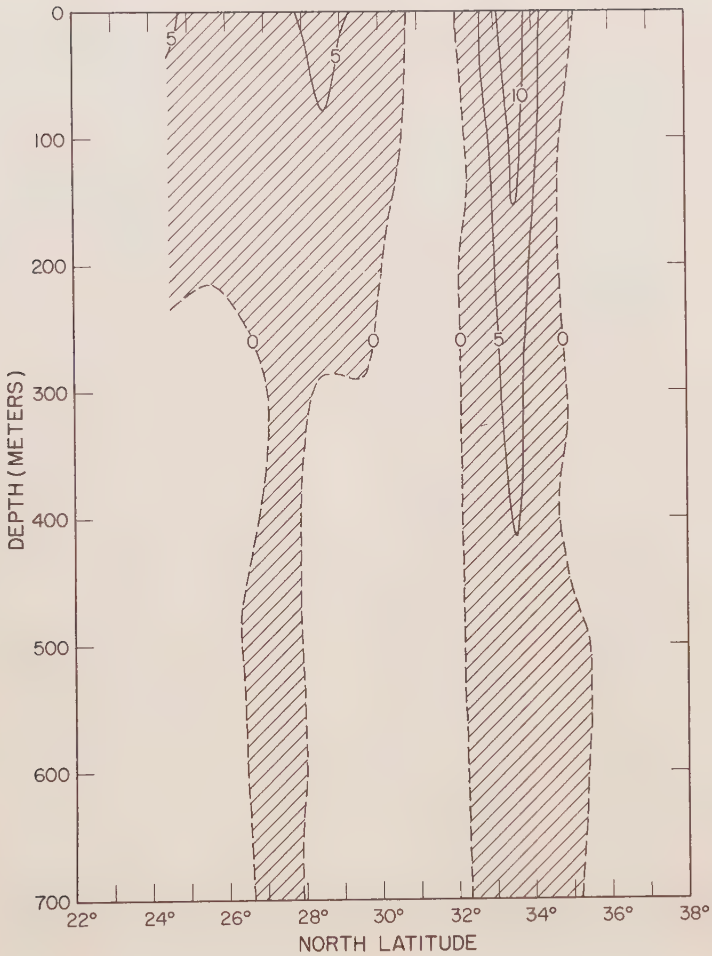


Figure 57.--Zonal components of the geostrophic currents in centimeters per second across 159° W. longitude; Hugh M. Smith cruise 27, January-February 1955. Hatched areas indicate easterly flow. Contour interval 5 cm. /sec.

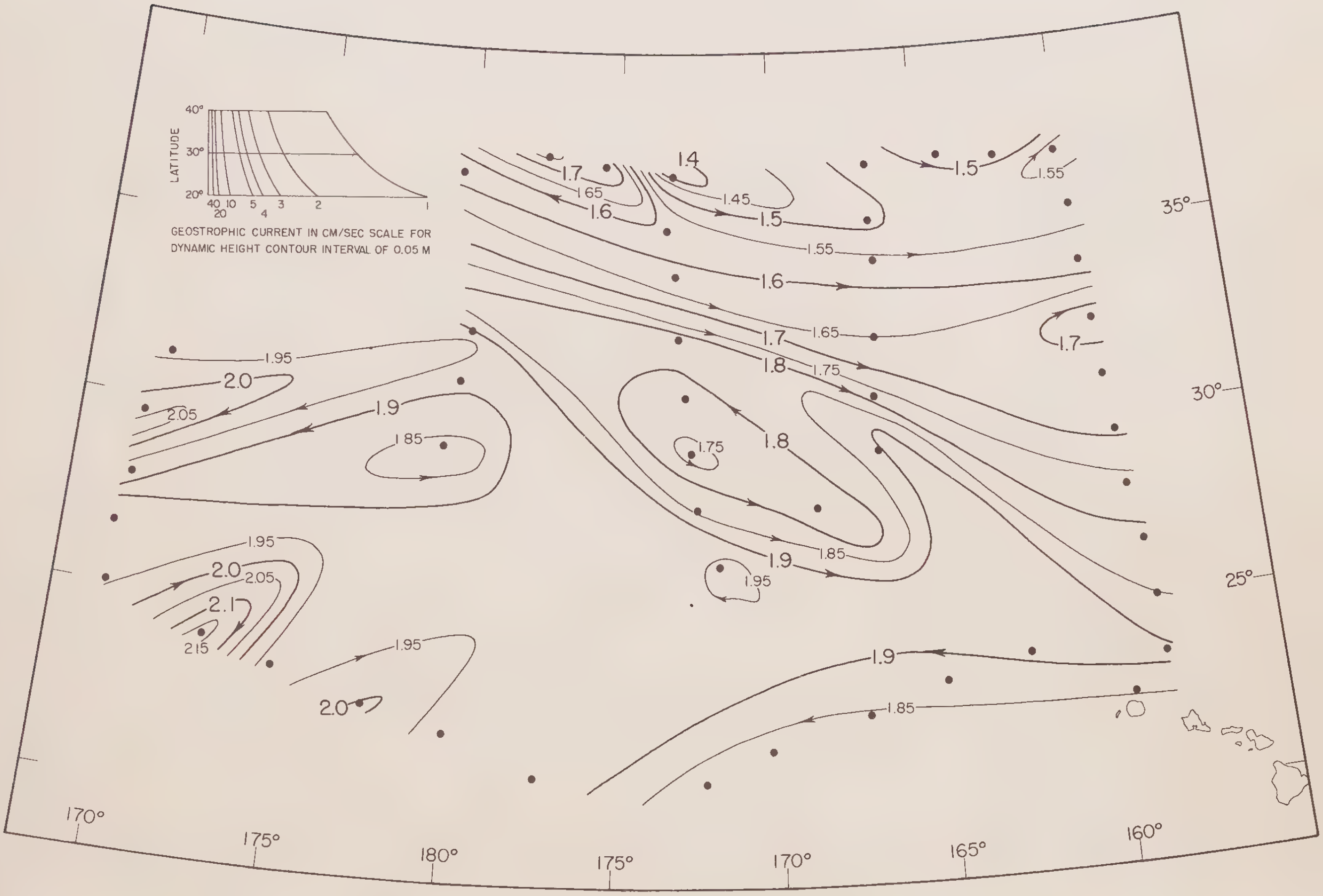
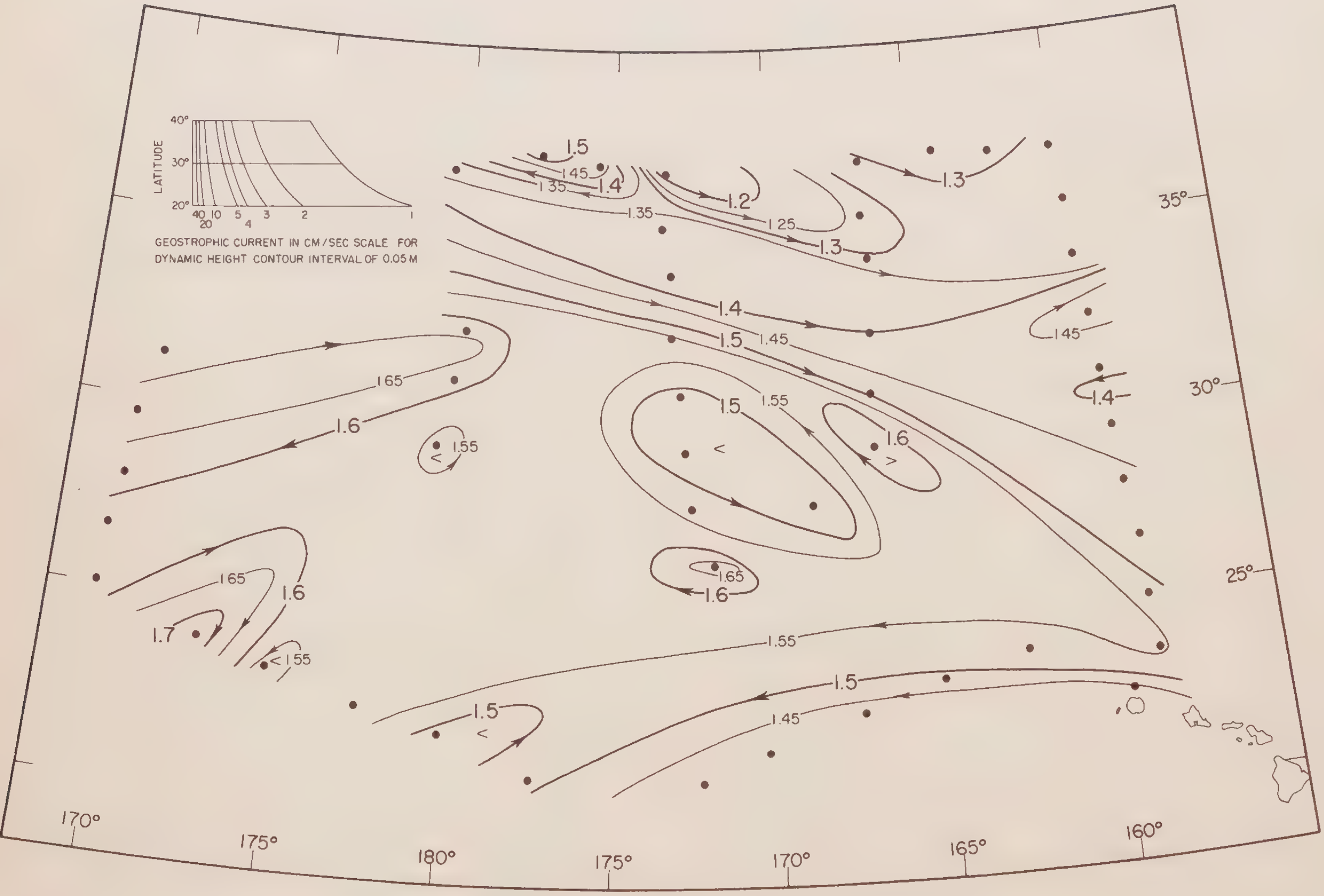

LATITUDE
40°
30°
20°
40
20
10
5
4
3
2
1
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR DYNAMIC HEIGHT CONTOUR INTERVAL OF 0.05 M
1.7
1.65
1.6
1.4
1.45
1.5
1.5
1.55
1.55
1.6
1.65
1.7
1.7
1.8
1.75
1.95
2.0
2.05
1.9
1.85
1.75
1.8
1.9
1.85
1.95
1.95
2.0
2.05
2.1
2.15
1.95
2.0
1.9
1.85
35°
30°
25°
170°
175°
180°
175°
170°
165°
160°

Figure 58.--Anomaly of the geopotential topography of the sea surface in dynamic meters relative to the 1,000-db. surface; Hugh M. Smith cruise 27, January-February 1955. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.05 m.



40°
30°
20°
LATITUDE
40 10 5 3 2 1
20 4
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR DYNAMIC HEIGHT CONTOUR INTERVAL OF 0.05 M
1.5
1.45
1.35
1.4
1.2
1.35
1.25
1.3
1.3
1.4
1.5
1.45
1.45
1.65
1.6
1.55
1.5
1.55
1.6
1.4
1.65
1.6
1.65
1.6
1.7
1.55
1.55
1.5
1.5
1.45
35°
30°
25°
170°
175°
180°
175°
170°
165°
160°

Figure 59.--Anomaly of the geopotential topography of the 100-db. surface in dynamic meters relative to the 1000-db. surface; Hugh M. Smith cruise 27, January-February 1955. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.05 m.

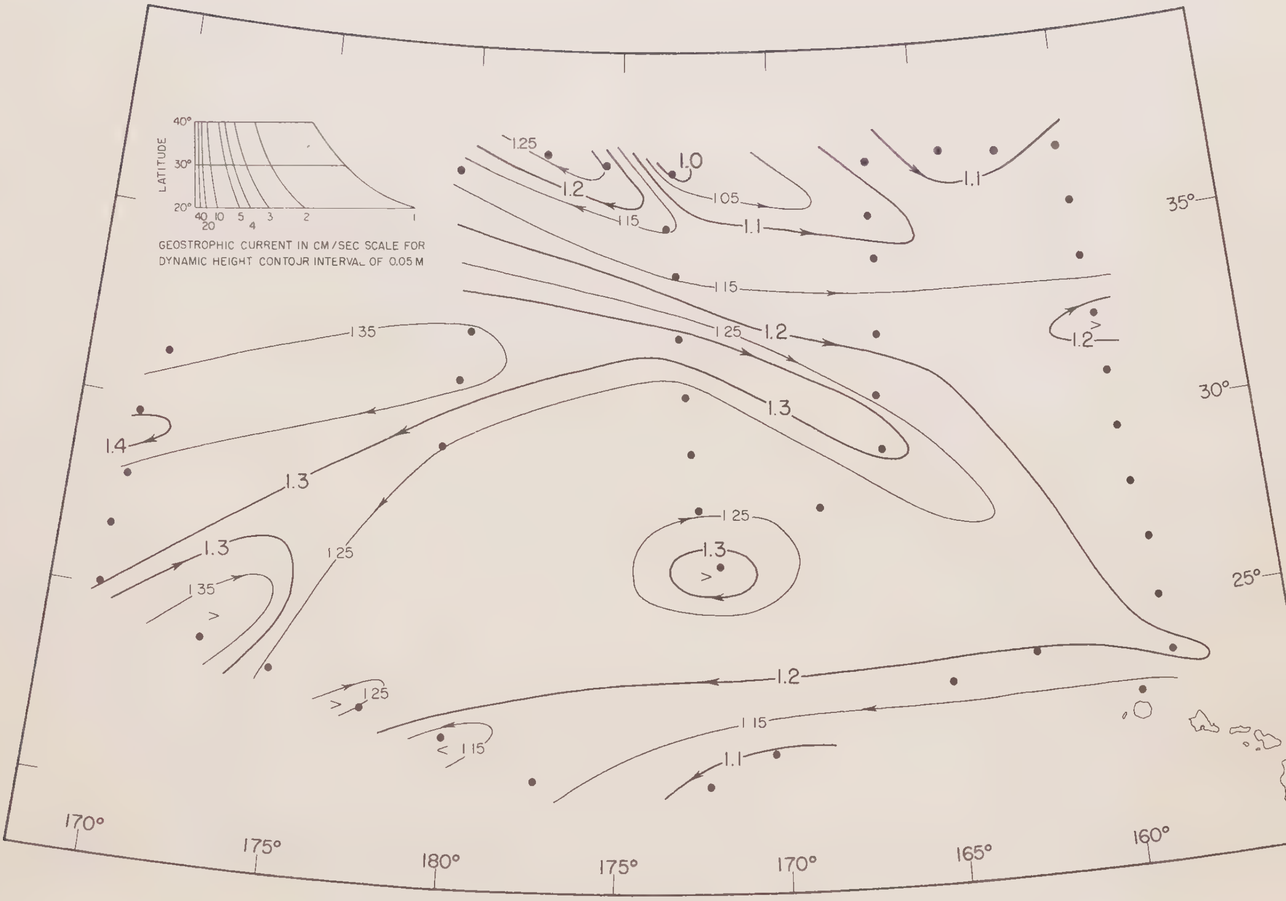
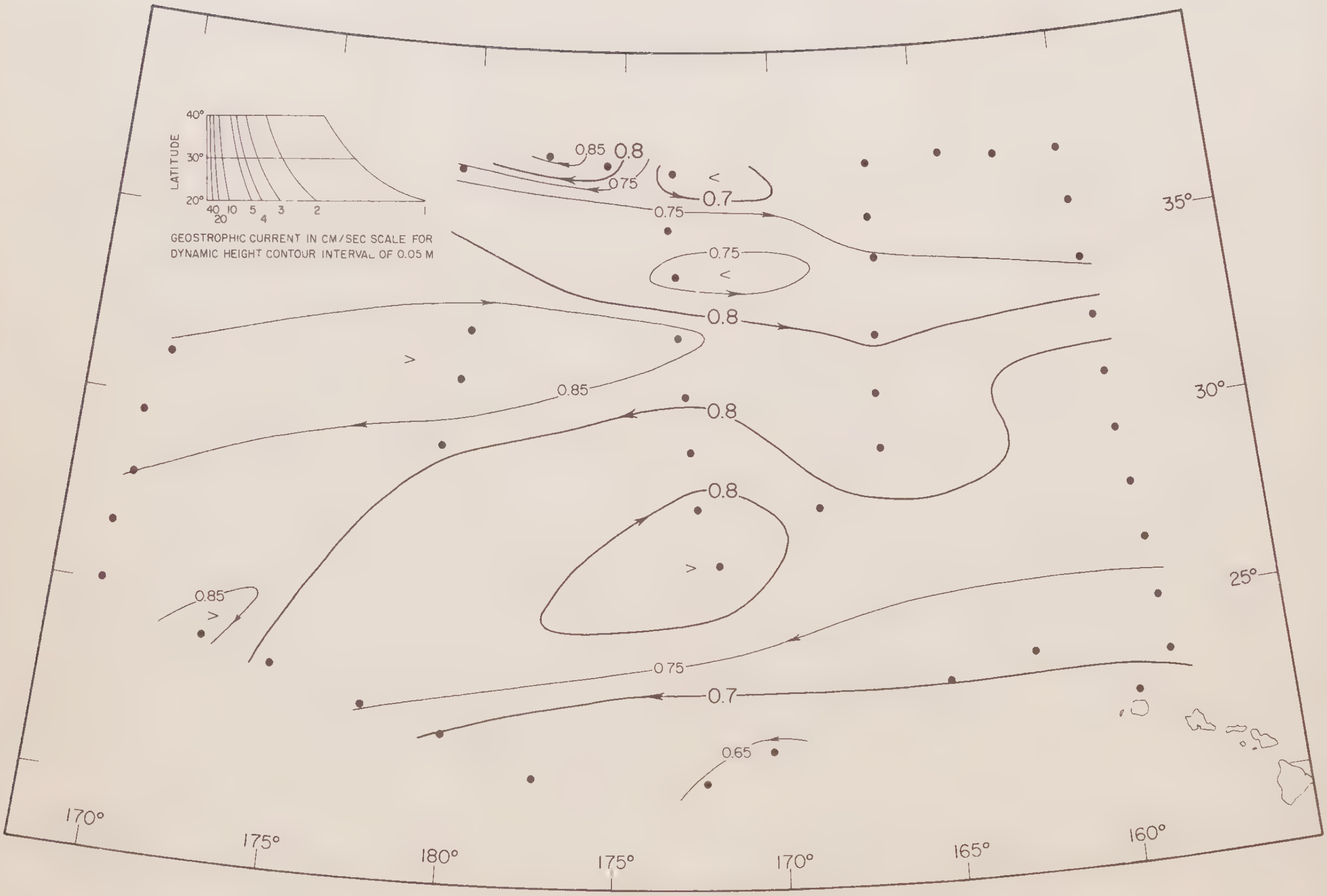

LATITUDE
40°
30°
20°
40 10 5 3 2 1
20 4
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR
DYNAMIC HEIGHT CONTOJR INTERVAL OF 0.05 M
1.25
1.2
1.0
1.05
1.15
1.1
1.1
1.15
1.25
1.2
1.2
1.35
1.4
1.3
1.3
1.3
1.35
1.25
1.25
1.3
1.2
1.25
1.15
1.15
1.1
35°
30°
25°
170°
175°
180°
175°
170°
165°
160°

Figure 60.--Anomaly of the geopotential topography of the 200-db. surface in dynamic meters relative to the 1000-db. surface; Hugh M. Smith cruise 27, January-February 1955. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.05 m.



40°
30°
20°
LATITUDE
40
20
10
5
4
3
2
1
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR
DYNAMIC HEIGHT CONTOUR INTERVAL OF 0.05 M
0.85
0.8
0.75
0.7
0.75
0.75
0.8
0.85
0.8
0.8
0.85
0.75
0.7
0.65
35°
30°
25°
170°
175°
180°
175°
170°
165°
160°

Figure 61.--Anomaly of the geopotential topography of the 400-db. surface in dynamic meters relative to the 1000-db. surface; Hugh M. Smith cruise 27, January-February 1955. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.05 m.

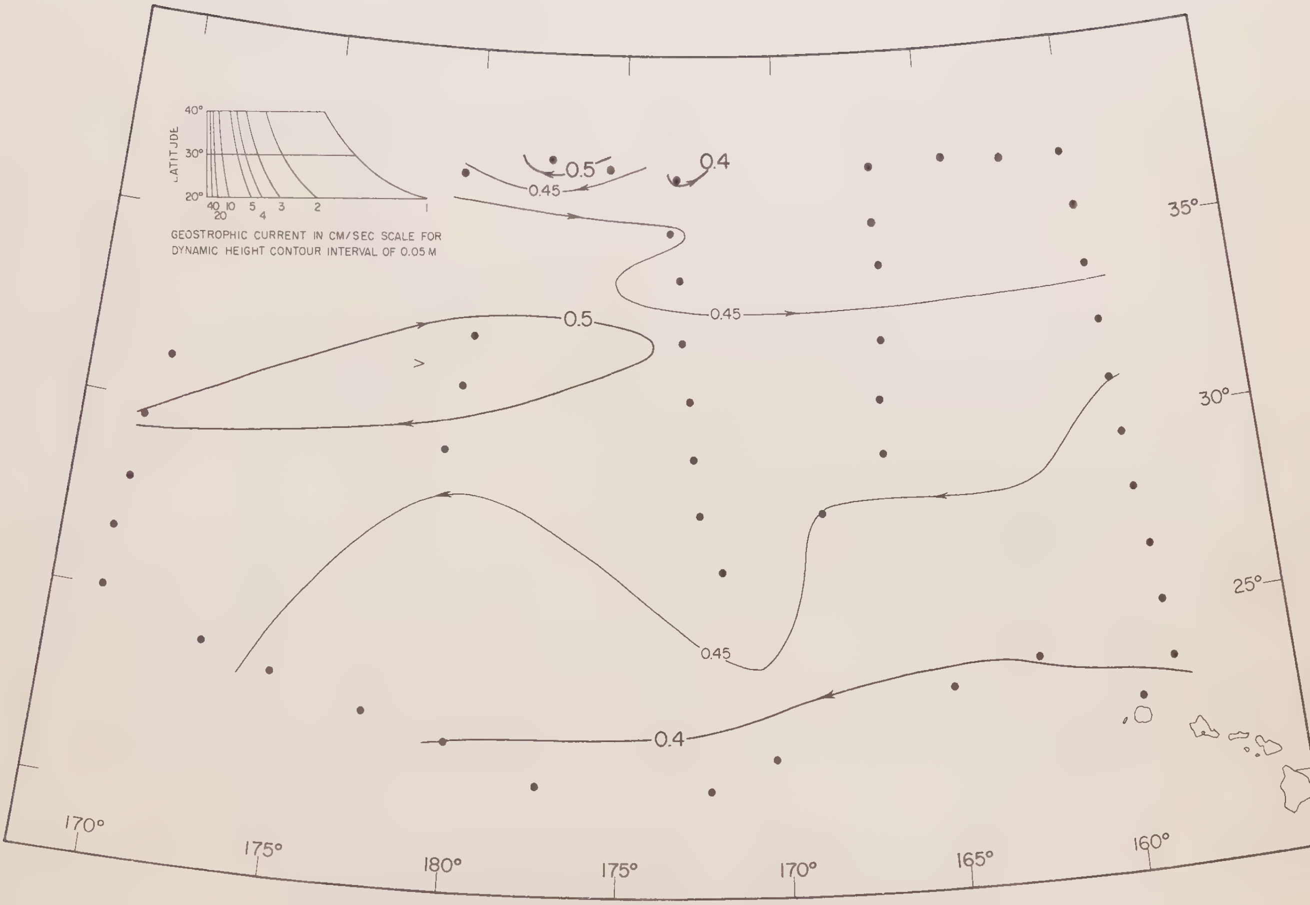
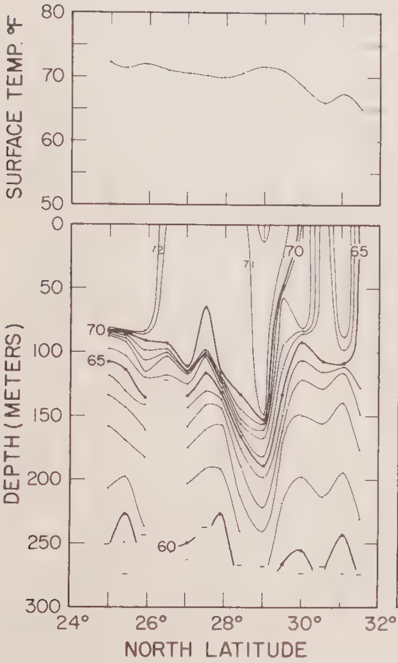
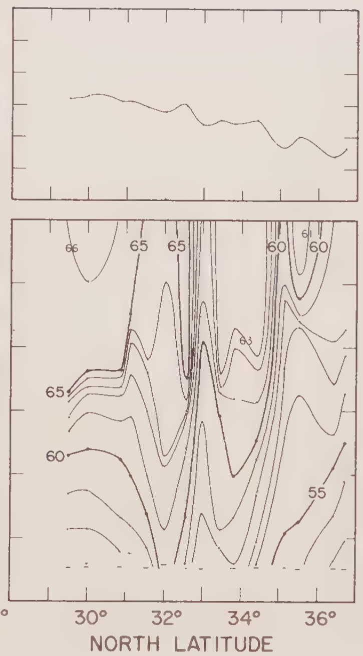

40°
LATITUDE
30°
20°
40 10 5 3 2 1
20 4
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR
DYNAMIC HEIGHT CONTOUR INTERVAL OF 0.05 M
0.5
0.45
0.4
0.45
0.5
0.45
0.4
35°
30°
25°
170°
175°
180°
175°
170°
165°
160°

Figure 62.--Anomaly of the geopotential topography of the 600-db. surface in dynamic meters relative to the 1000-db. surface; Hugh M. Smith cruise 27, January-February 1955. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.05 m.





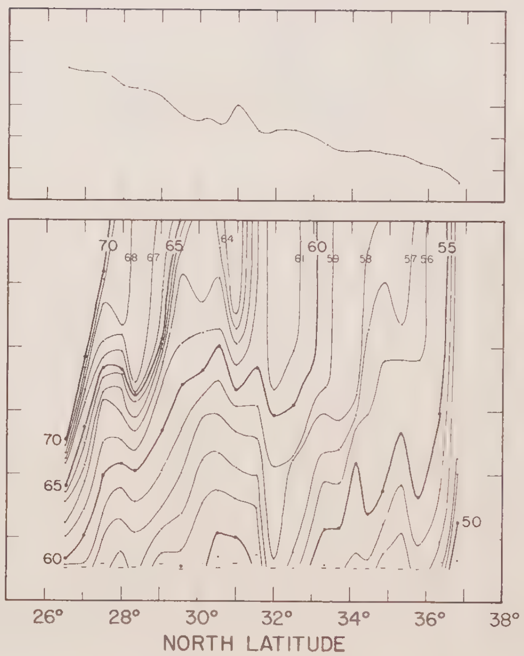
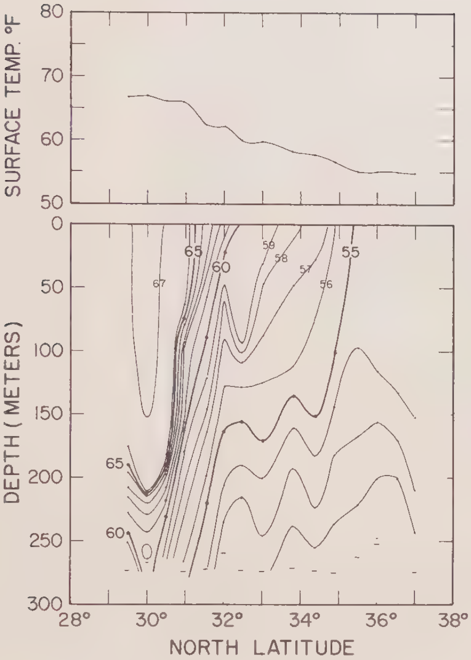


Figure 63.--Surface (bucket) temperatures (upper panel) and temperature-depth section (lower panel) in degrees Fahrenheit along 170°E. longitude from BT observations; Hugh M. Smith cruise 27, January-February 1955. Contour interval 1°F. Small dashes indicate the depth of lowering.

Figure 64.--Same along the 180th meridian.

Figure 65.--Same along 172°W. longitude.



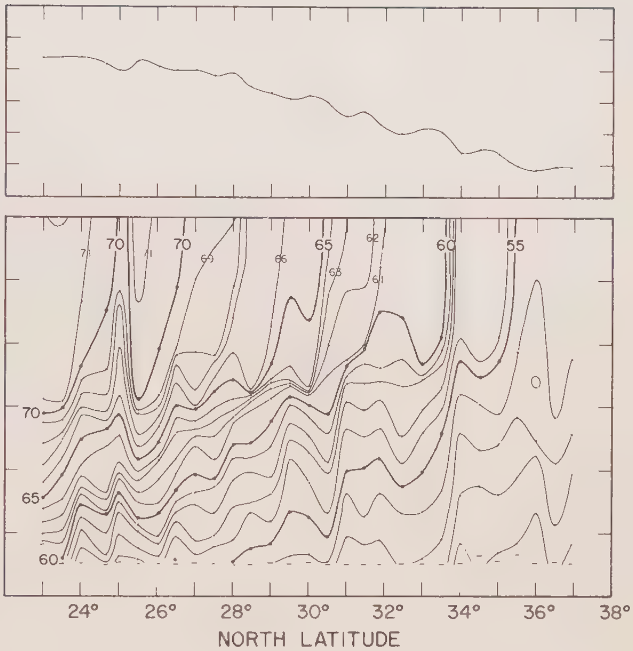


Figure 66.--Surface (bucket) temperatures (upper panel) and temperature-depth section (lower panel) in degrees Fahrenheit along 167°W. longitude from BT observations; Hugh M. Smith cruise 27, January-February 1955. Contour interval 1°F. Small dashes indicate the depth of lowering.

Figure 67.--Same along 159°W. longitude.

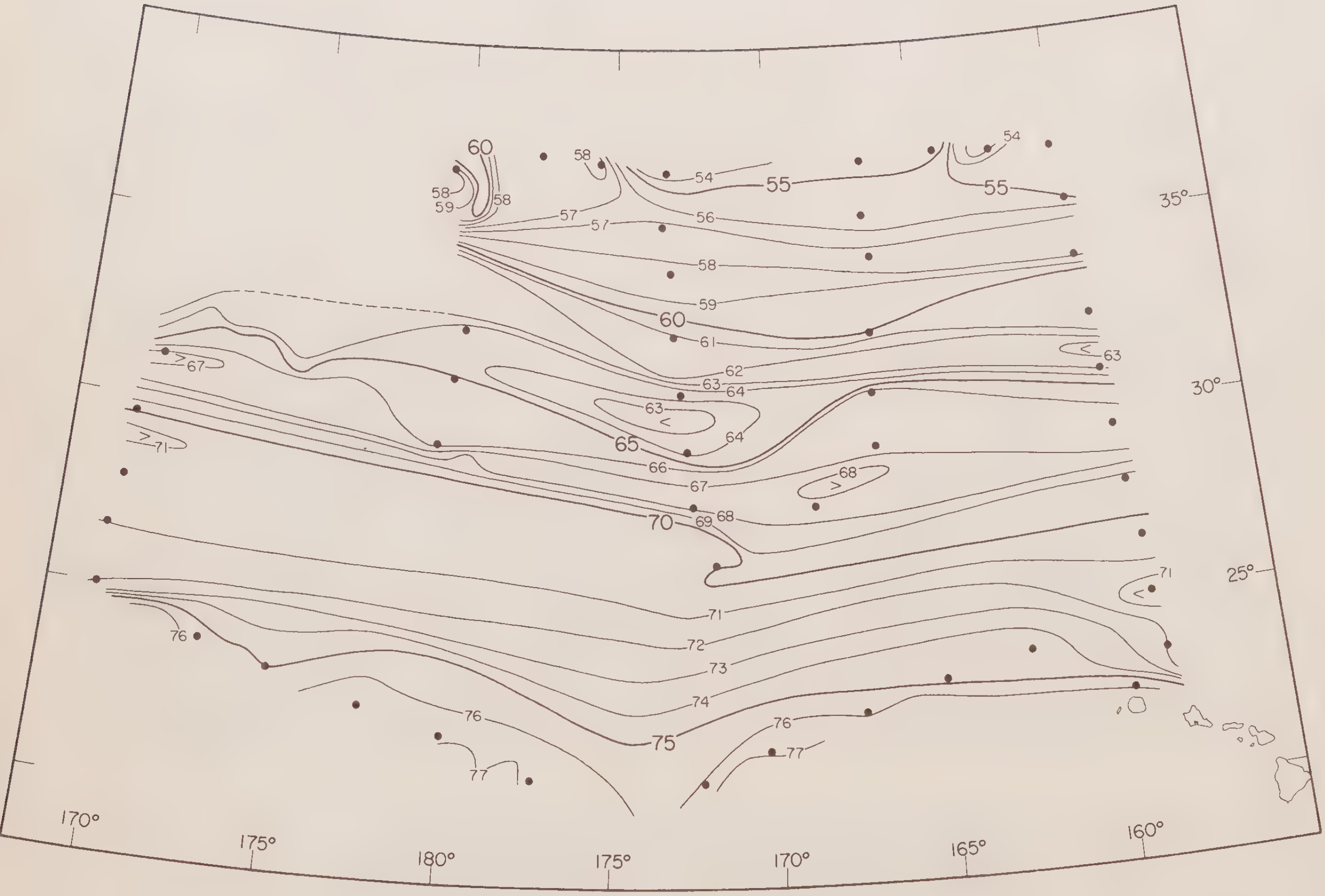

60
58
54
54
55
55
58
59
58
57
57
56
35°
58
59
60
61
62
63
63
64
67
63
30°
65
64
71
66
68
67
70
69
68
25°
71
71
76
72
73
74
76
75
76
77
77
170°
175°
180°
175°
170°
165°
160°

Figure 68.--Surface (bucket) temperatures in degrees Fahrenheit; Hugh M. Smith cruise 27, January-February 1955. Contour interval 1°F.

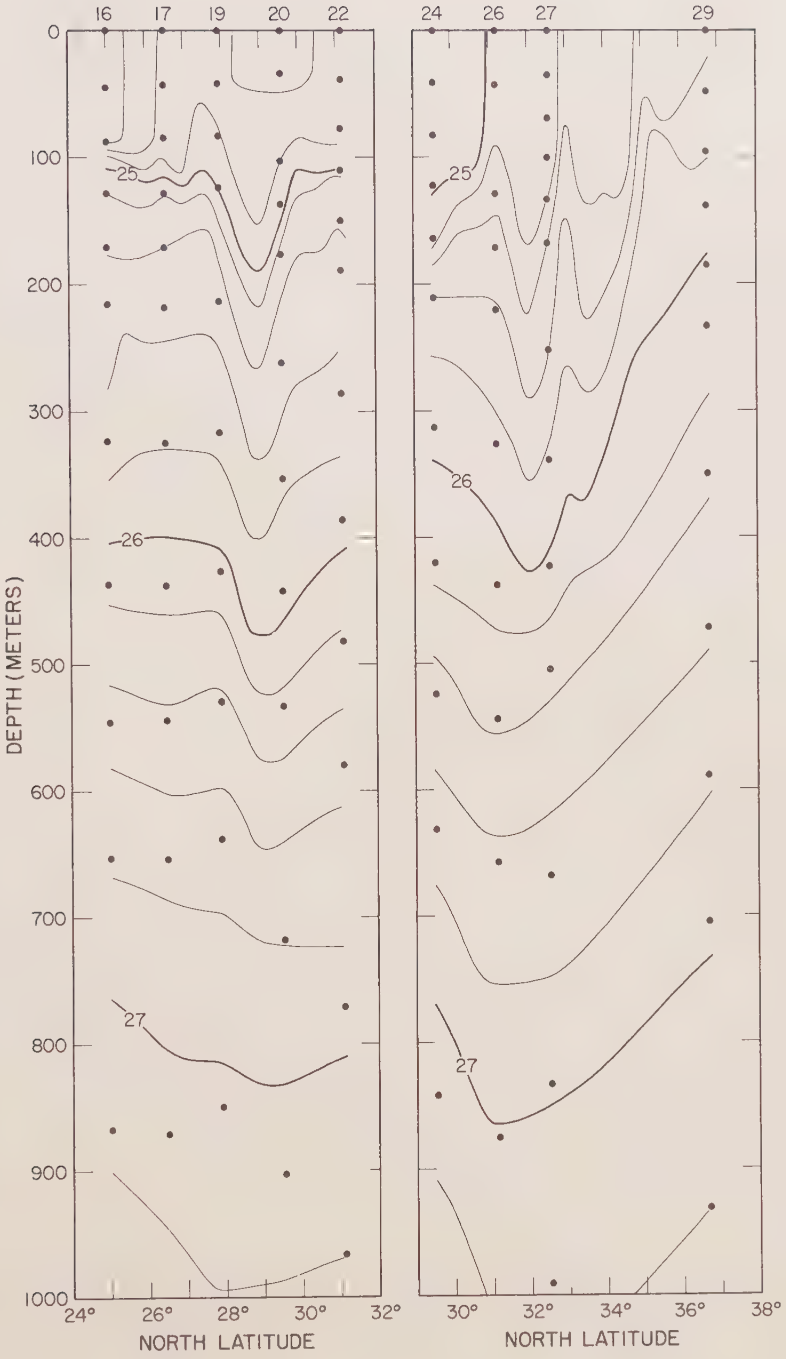


Figure 69.--Vertical section of sigma-t along 170°E. longitude; Hugh M. Smith cruise 27, stations 16-22, January-February 1955. Contour interval 0.2. Points indicate observed values.

Figure 70.--Same along 180th meridian, stations 24-29.

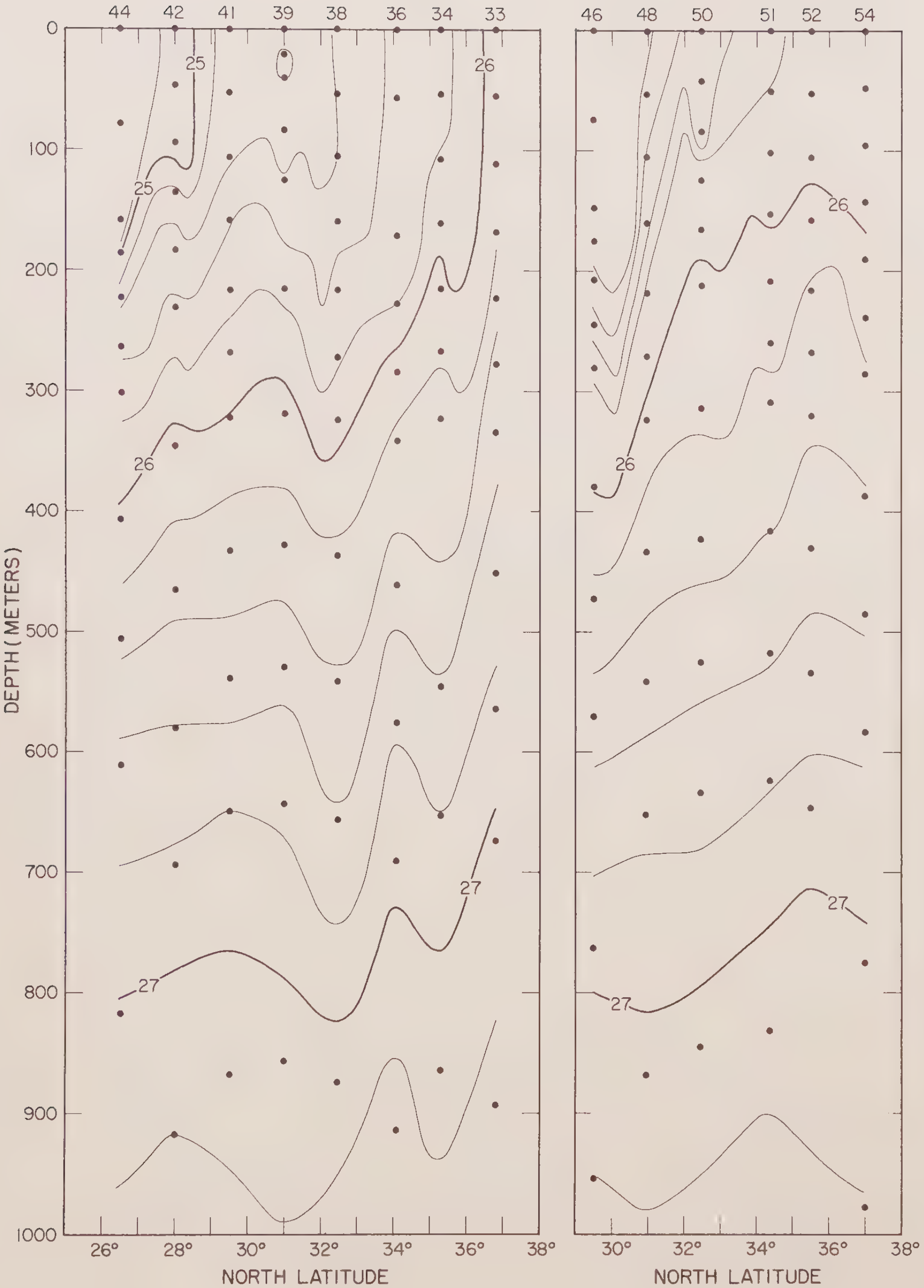


Figure 71.--Vertical section of sigma-t along 172°W. longitude; Hugh M. Smith cruise 27, stations 33-44, January-February 1955. Contour interval 0.2. Points indicate observed values.

Figure 72.--Same along 167°W. longitude, stations 46-54.

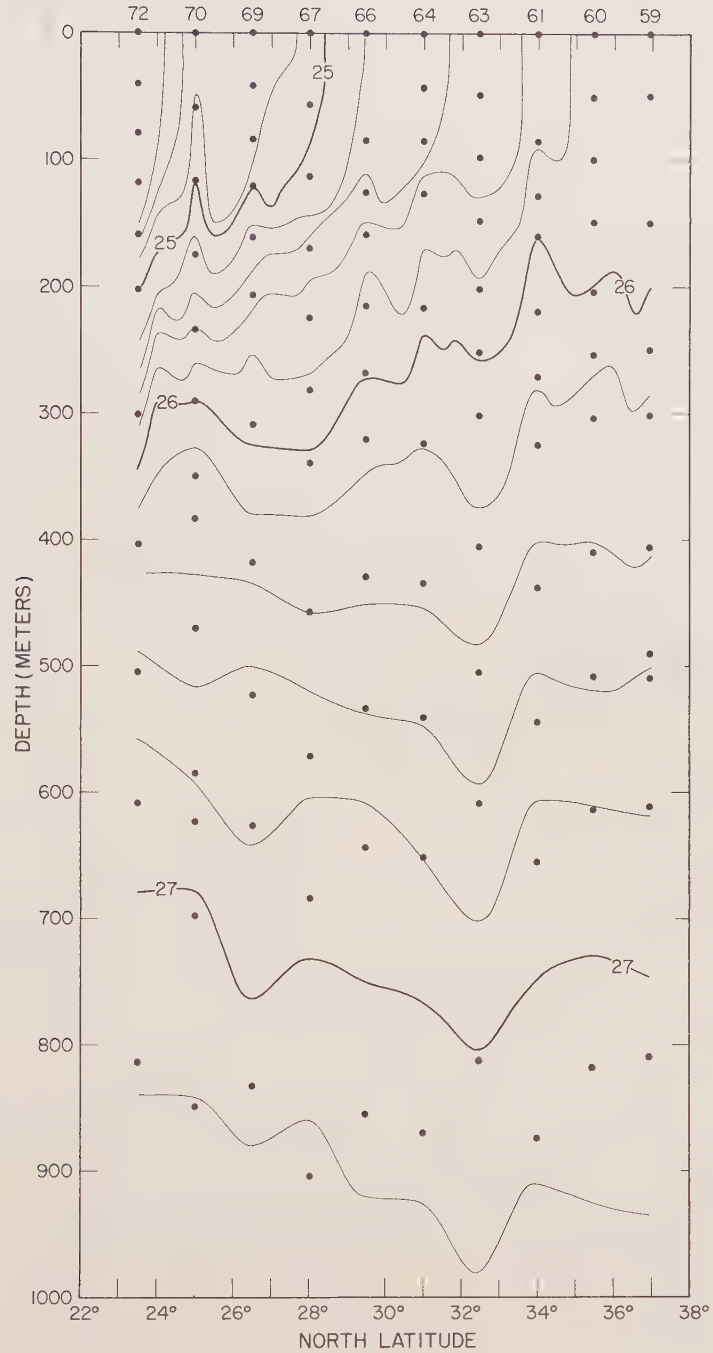


Figure 73.--Vertical section of sigma-t along 159°W. longitude; Hugh M. Smith cruise 27, stations 59-72, January-February 1955. Contour interval 0.2. Points indicate observed values.

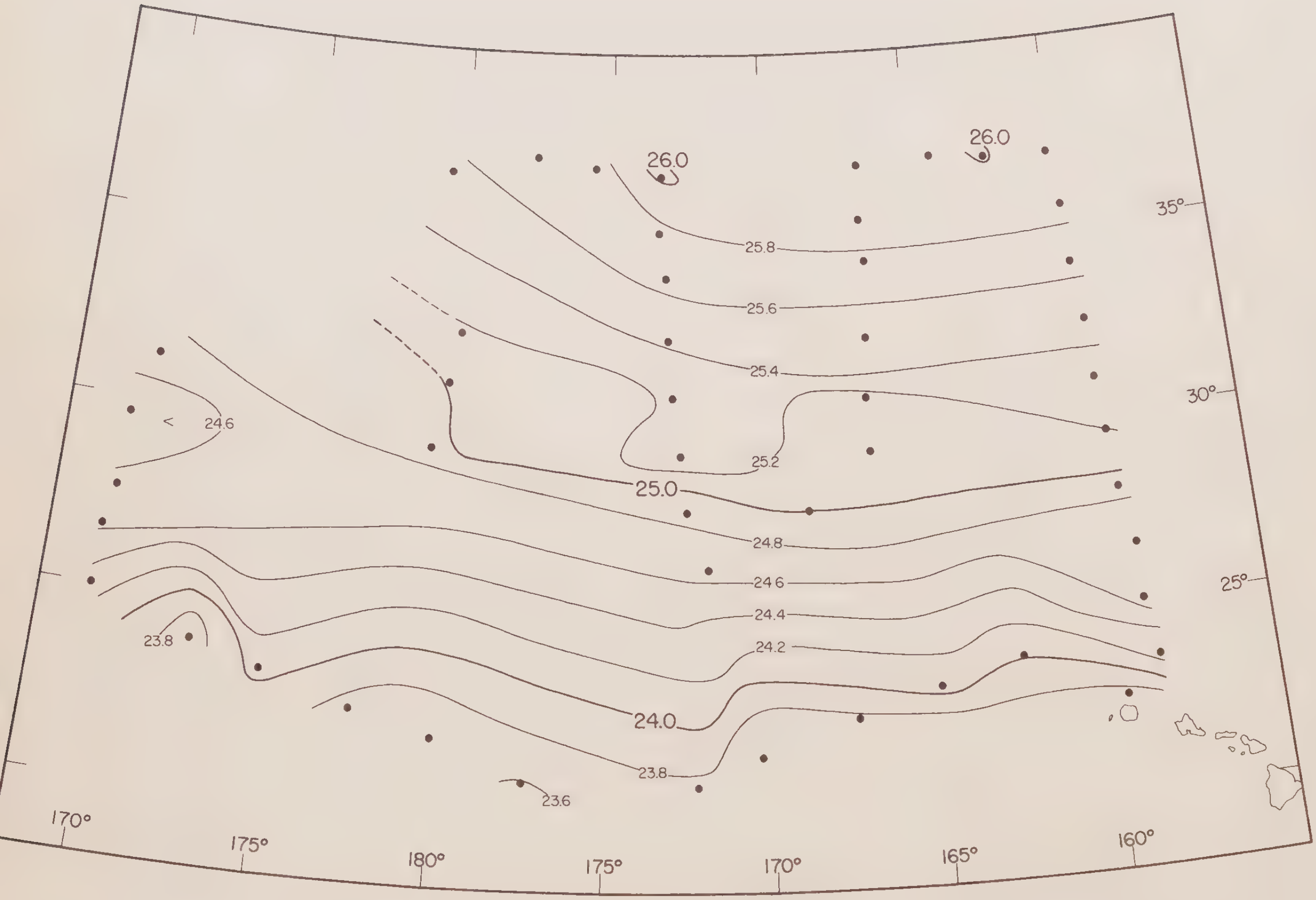

26.0
26.0
35°
25.8
25.6
25.4
30°
24.6
25.2
25.0
24.8
24.6
25°
24.4
24.2
23.8
24.0
23.8
23.6
170°
175°
180°
175°
170°
165°
160°

Figure 74.--Surface sigma-t; *Hugh M. Smith* cruise 27, January-February 1955. Contour interval 0.2. Dots indicate station positions.

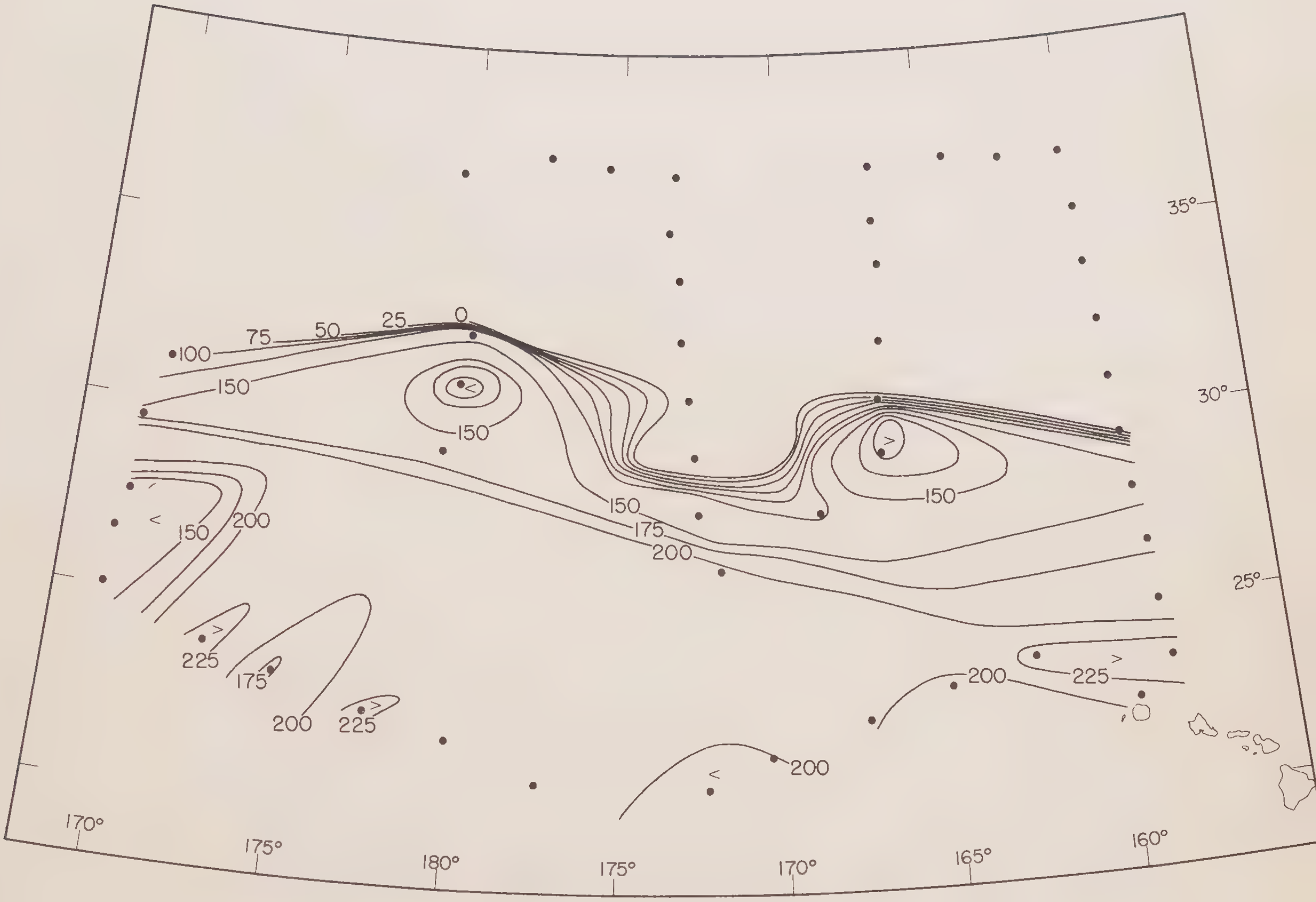

35°
30°
25°
0
25
50
75
100
150
150
150
150
175
200
150
200
225
175
200
225
150
175
200
200
225
200
170°
175°
180°
175°
170°
165°
160°

Figure 75.--Depth of the 25.2 sigma-t surface in meters; Hugh M. Smith cruise 27, January-February 1955. Contour interval 25 m. Dots indicate station positions.

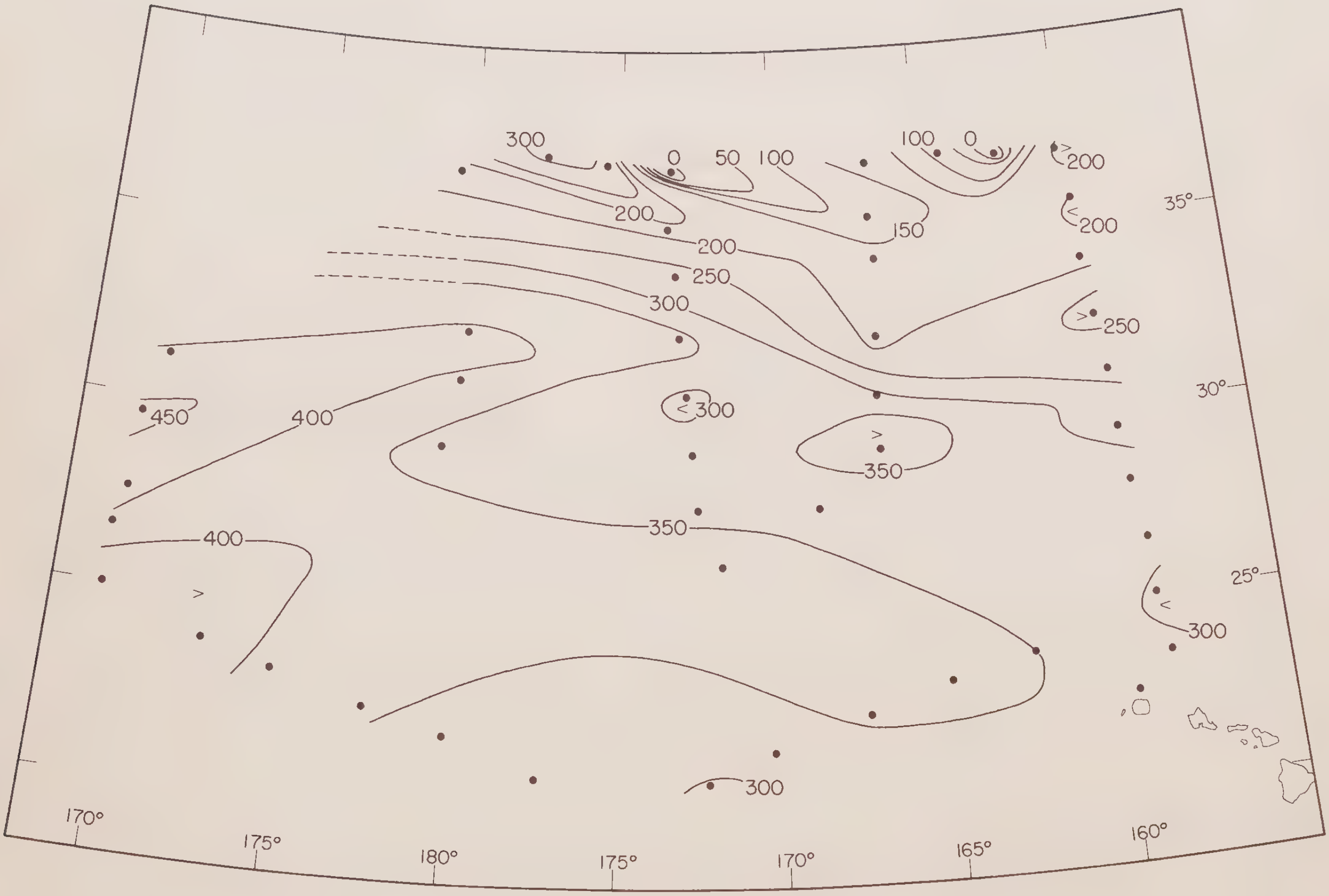

300
0
50
100
100
0
>200
200
<200
150
200
250
>250
300
35°
30°
450
400
<300
>
350
350
400
>
25°
<
300
300
170°
175°
180°
175°
170°
165°
160°

Figure 76.--Depth of the 26.0 sigma-t surface in meters; *Hugh M. Smith* cruise 27, January-February 1955. Contour interval 50 m. Dots indicate station positions.

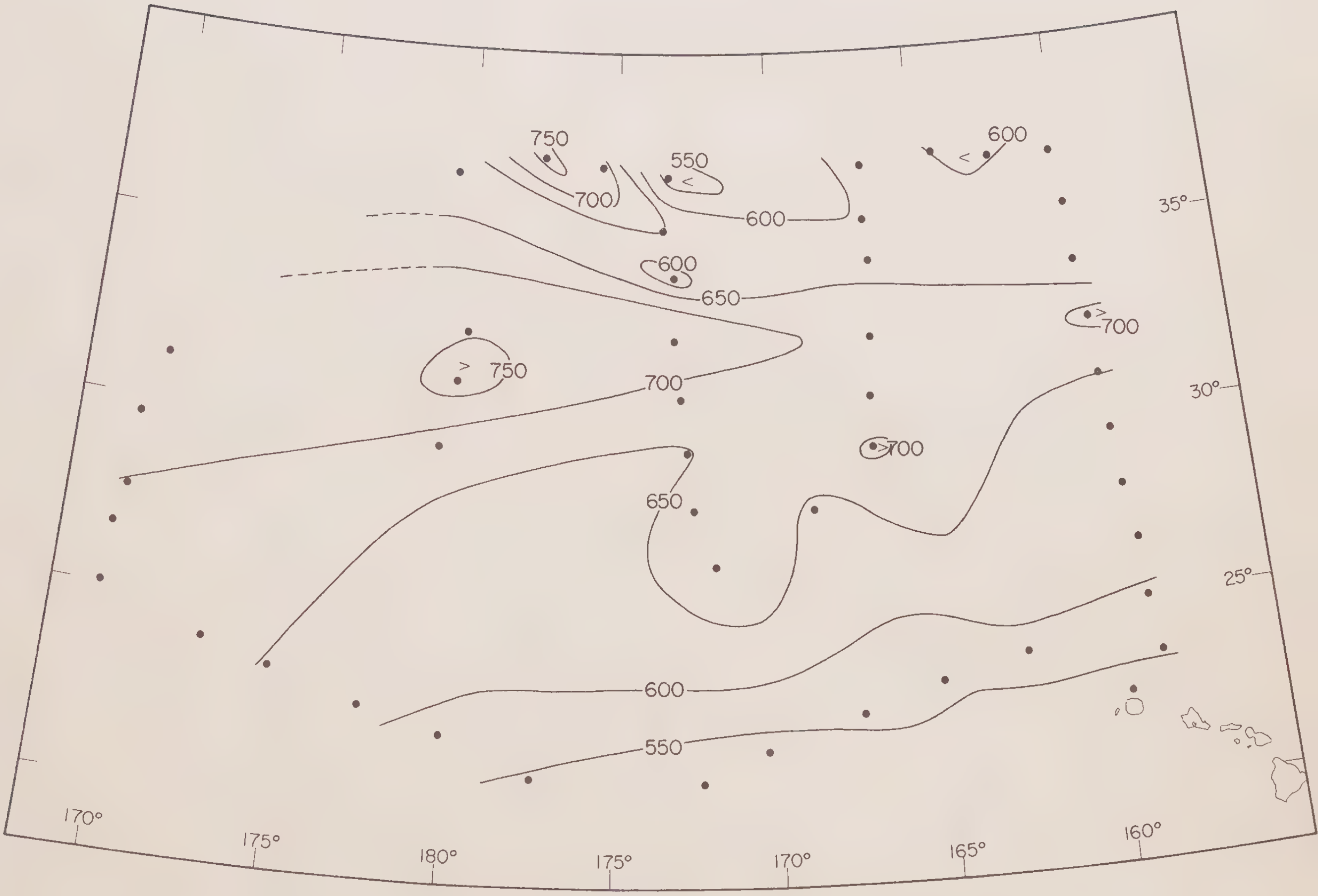
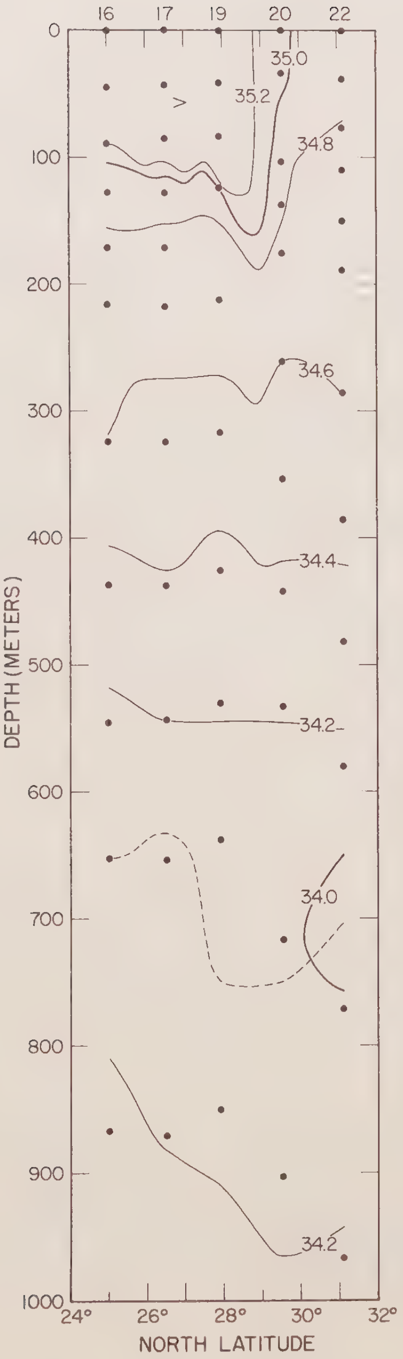

750
550
600
700
600
600
650
700
750
700
700
650
600
550
35°
30°
25°
170°
175°
180°
175°
170°
165°
160°

Figure 77.--Depth of the 26.8 sigma-t surface in meters; Hugh M. Smith cruise 27, January-February 1955. Contour interval 50 m. Dots indicate station positions.



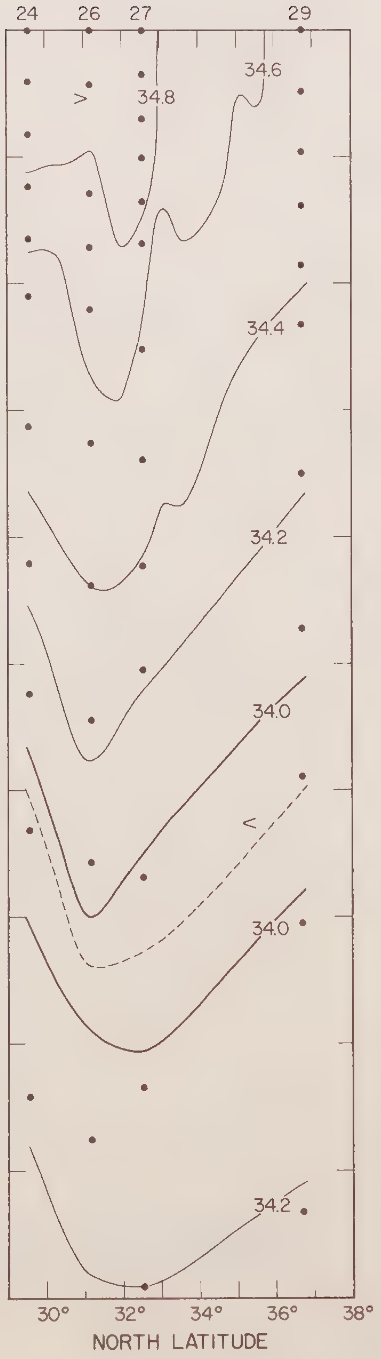
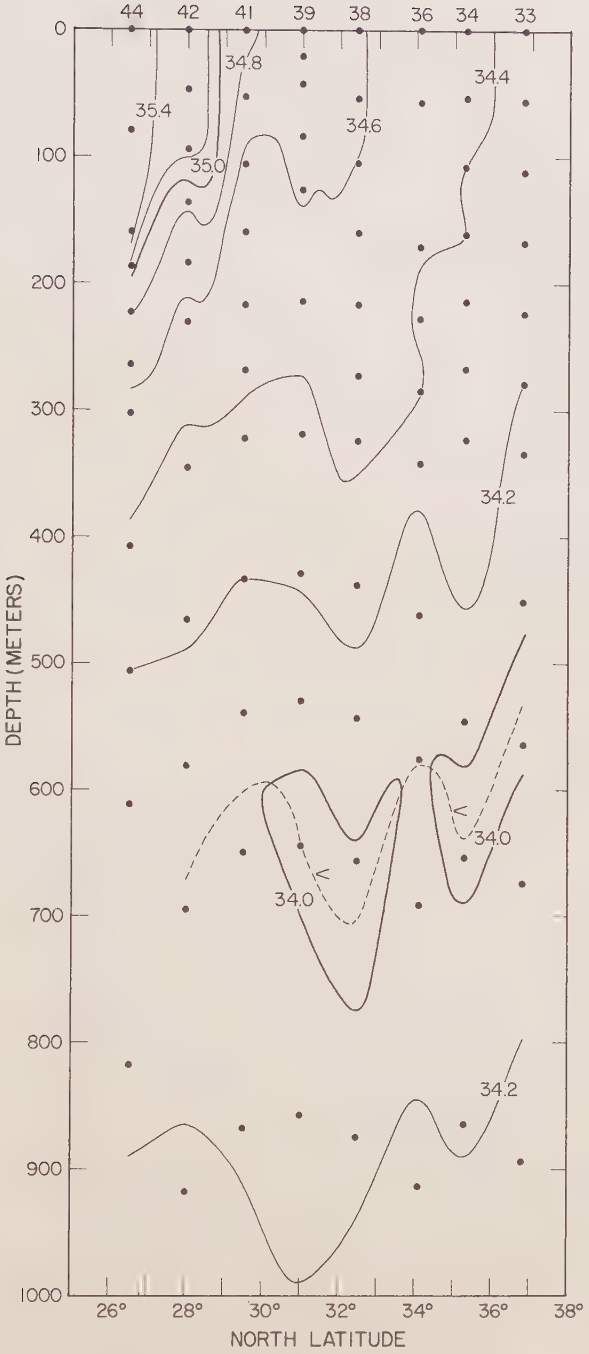


Figure 78.--Vertical section of salinity in parts per thousand along 170°E. longitude; Hugh M. Smith cruise 27, stations 16-22, January-February 1955. Points indicate observed values. Dotted lines indicate depth of salinity minima.

Figure 79.--Same along 180th meridian, stations 24-29.



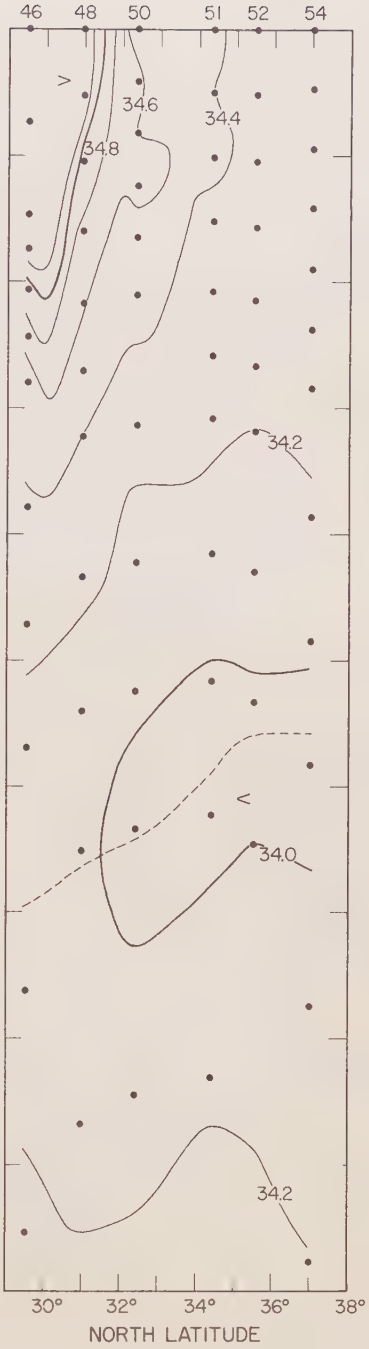


Figure 80.--Vertical section of salinity in parts per thousand along 172° W. longitude; Hugh M. Smith cruise 27, stations 33-44, January-February 1955. Points indicate observed values. Dotted lines indicate depth of salinity minima.

Figure 81.--Same along 167° W. longitude, stations 46-54.

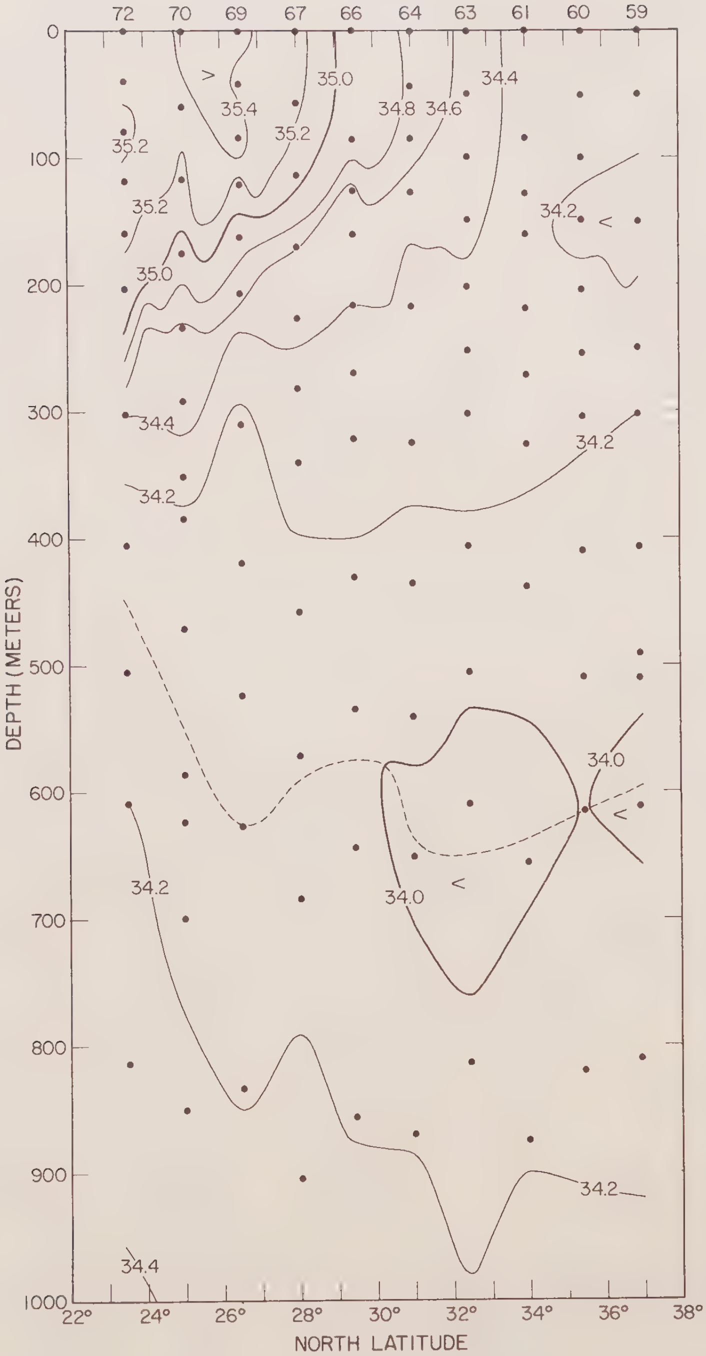


Figure 82.--Vertical section of salinity in parts per thousand along 159°W. longitude; Hugh M. Smith cruise 27, stations 59-72, January-February 1955. Points indicate observed values. Dotted lines indicate depth of salinity minima.

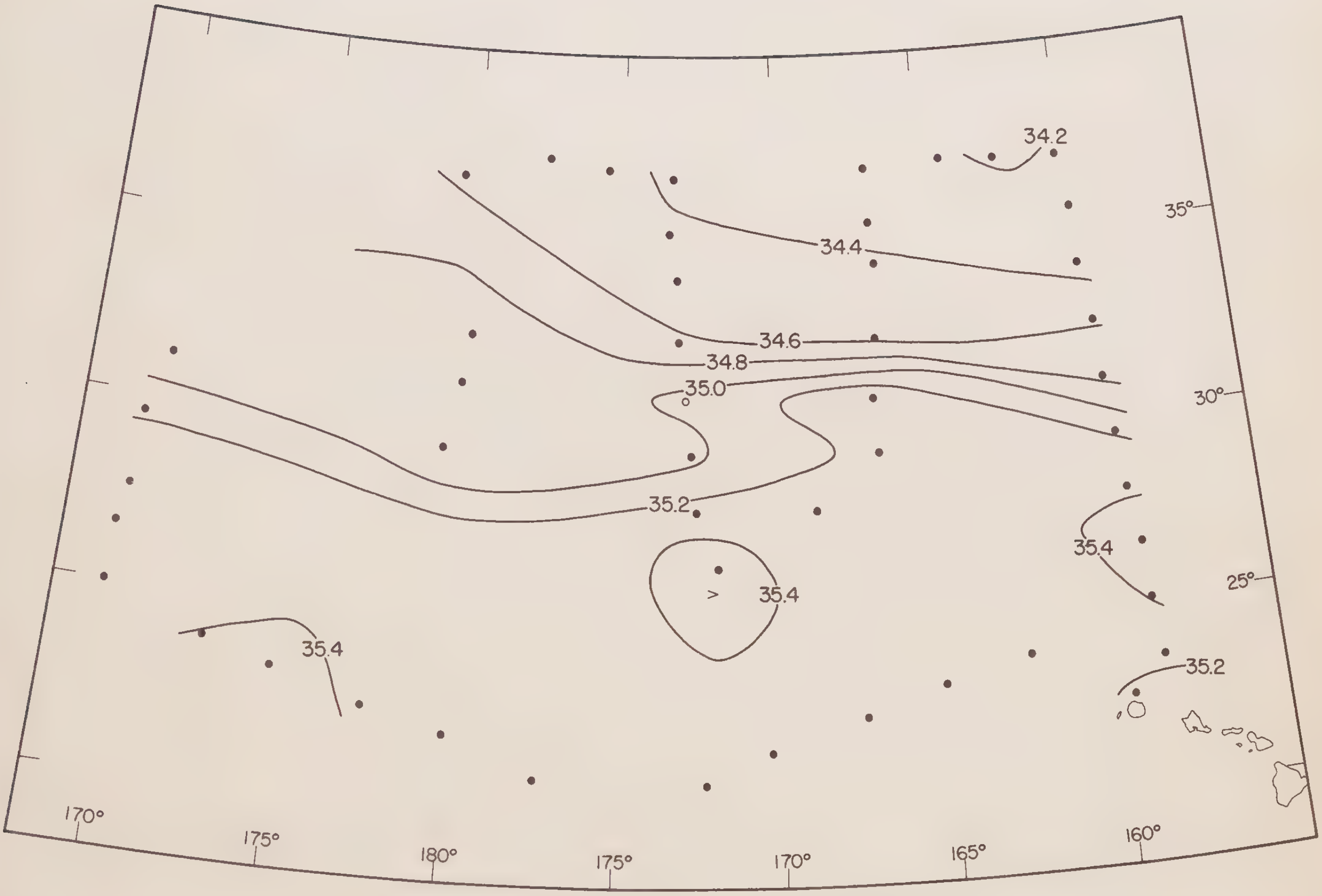

34.2
34.4
34.6
34.8
35.0
35.2
35.4
>
35.4
35.4
35.2
35°
30°
25°
170°
175°
180°
175°
170°
165°
160°

Figure 83.--Surface salinity in parts per thousand; Hugh M. Smith cruise 27, January-February 1955. Contour interval 0.2 ‰. Dots indicate observed values.

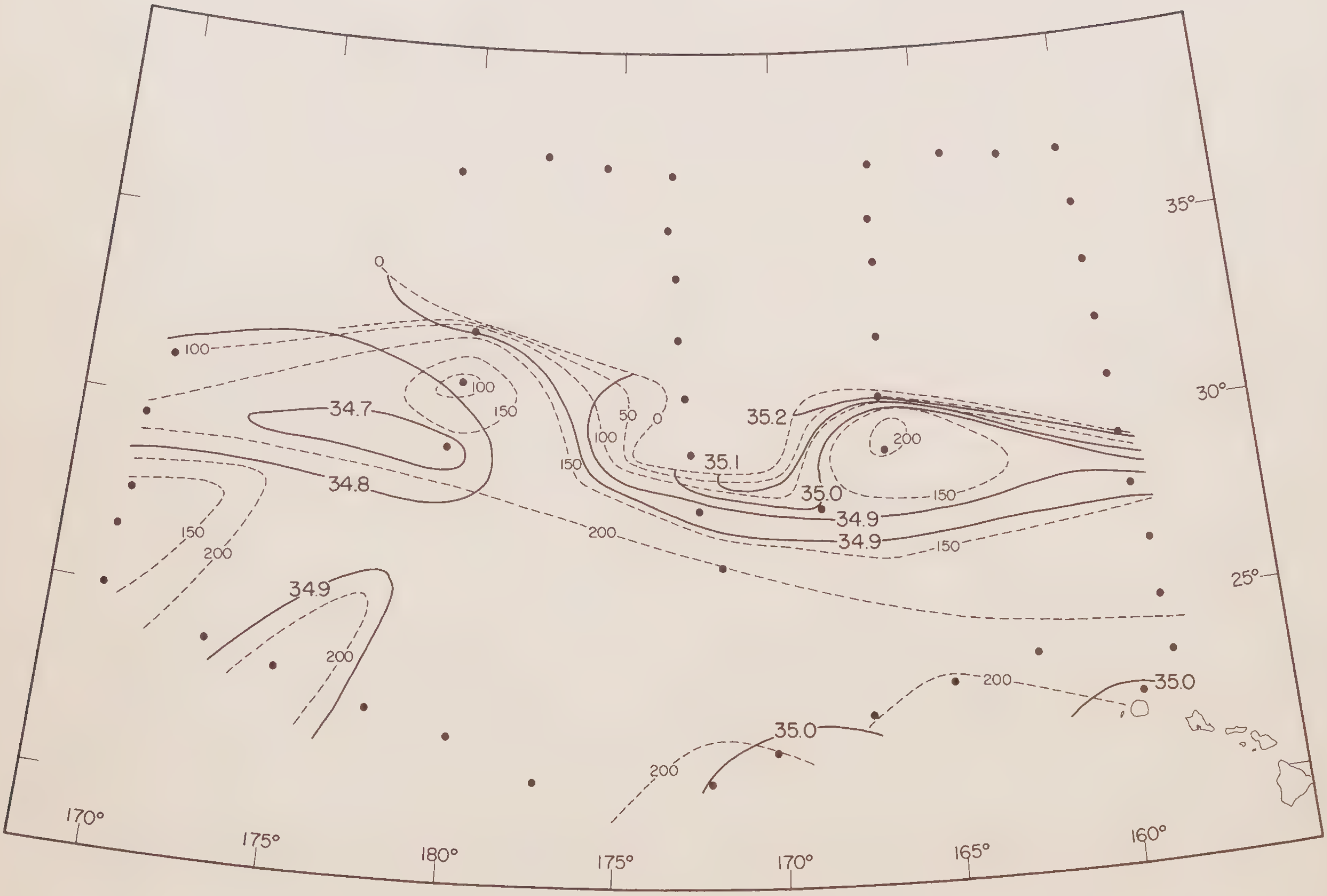

35°
30°
25°
170°
175°
180°
175°
170°
165°
160°
0
100
100
150
50
0
100
150
200
150
200
200
200
200
150
150
200
200
34.7
34.8
34.9
35.2
35.1
35.0
34.9
34.9
35.0
35.0

Figure 84.--Salinity in parts per thousand (solid lines) on the 25.2 sigma-t surface (depth in meters, dotted lines); Hugh M. Smith cruise 27, January-February 1955. Contour intervals: salinity 0.1 ‰, depth of sigma-t surface 50 m. Dots indicate station positions.

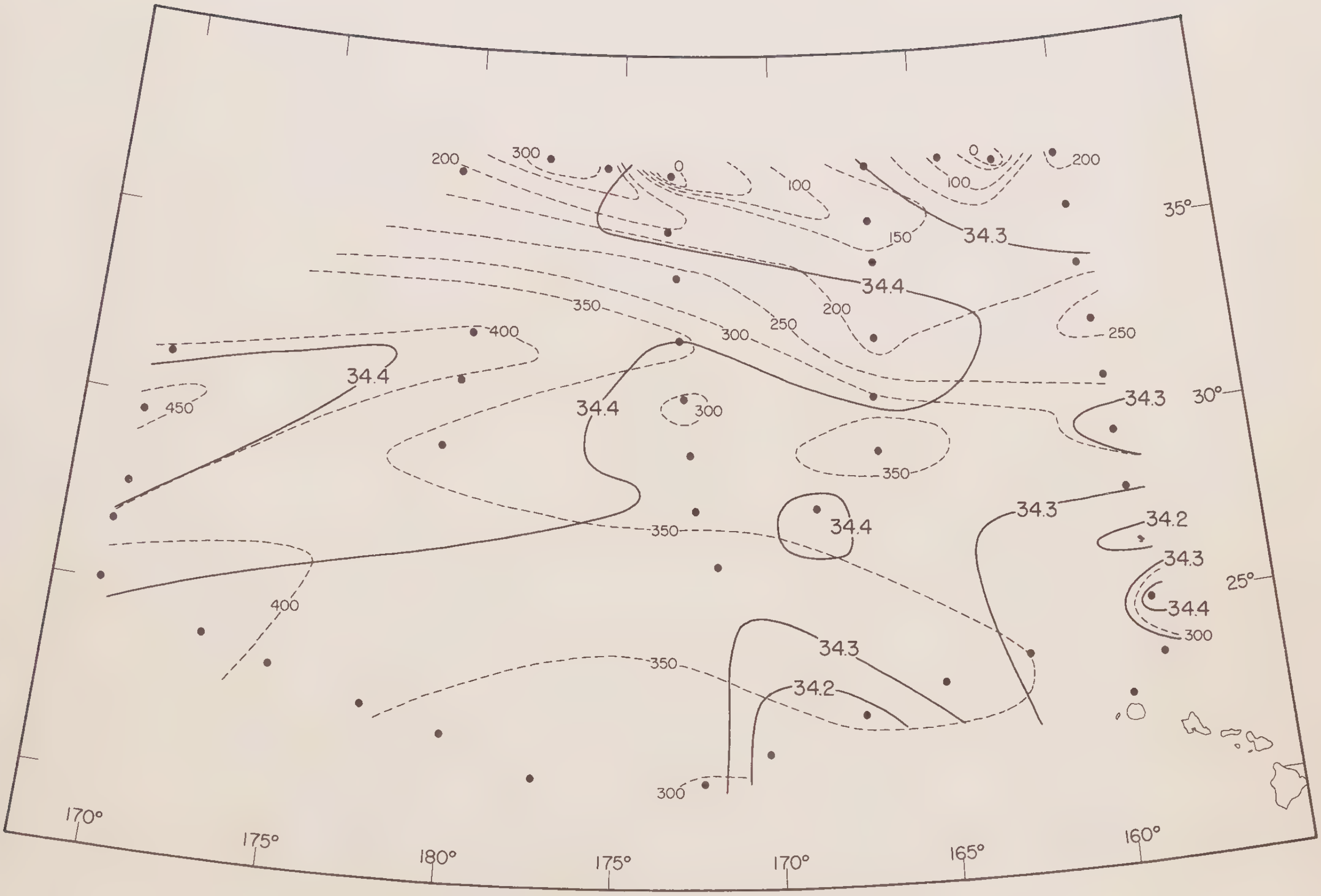

200
300
0
100
0
100
200
150
34.3
35°
34.4
350
200
250
300
250
400
34.4
450
34.4
300
34.3
30°
350
34.3
34.2
350
34.4
34.3
25°
400
34.4
300
34.3
350
34.2
300
170°
175°
180°
175°
170°
165°
160°

Figure 85. --Salinity in parts per thousand (solid lines) on the 26.0 sigma-t surface (depth in meters, dotted lines); Hugh M. Smith cruise 27, January-February 1955. Contour intervals: salinity 0.1 ‰, depth of sigma-t surface 50 m. Dots indicate station positions.

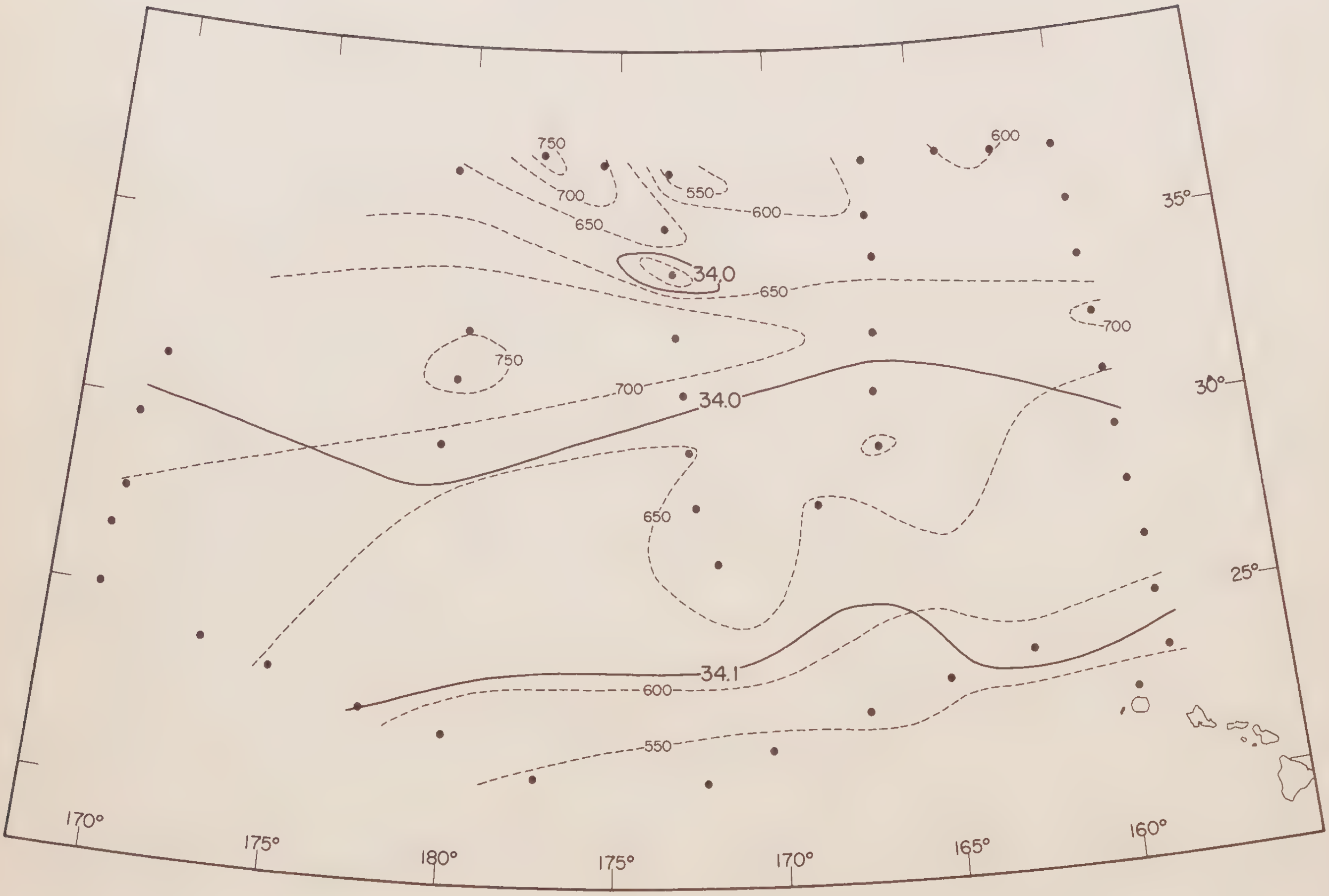

750
700
650
550
600
600
34.0
650
700
750
700
34.0
650
34.1
600
550
35°
30°
25°
170°
175°
180°
175°
170°
165°
160°

Figure 86.--Salinity in parts per thousand (solid lines) on the 26.8 sigma-t surface (depth in meters, dotted lines); *Hugh M. Smith* cruise 27, January-February 1955. Contour intervals: salinity 0.1 ‰, depth of sigma-t surface 50 m. Dots indicate station positions.

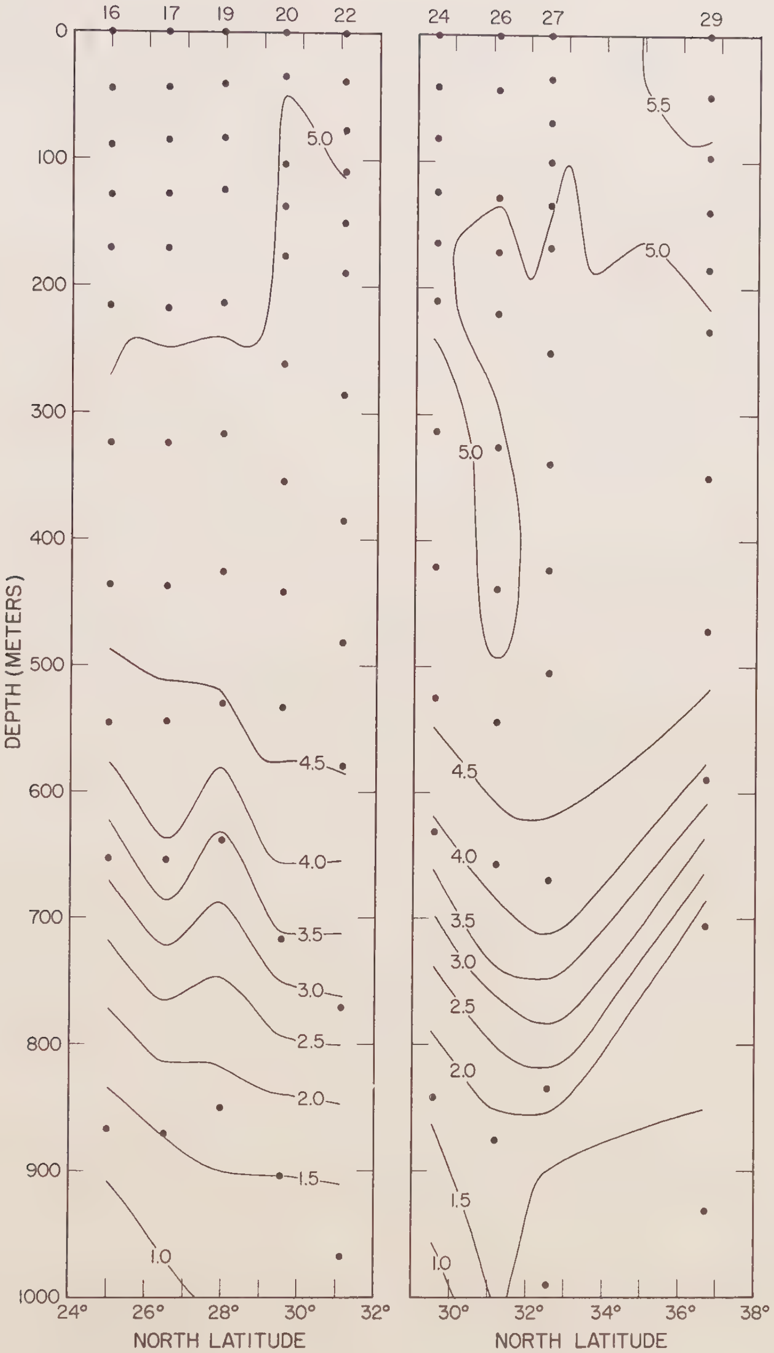
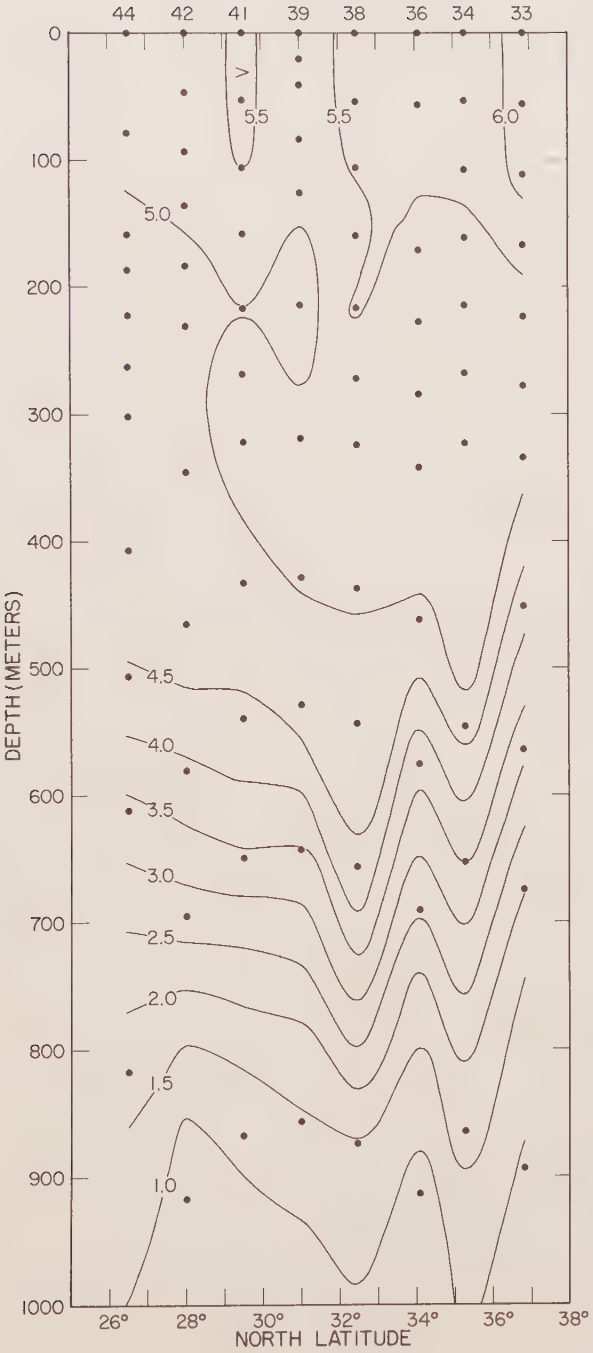


Figure 87.--Vertical section of dissolved oxygen in milliliters per liter along 170°E. longitude; Hugh M. Smith cruise 27, stations 16-22, January-February 1955. Contour interval 0.5 ml. /l.

Figure 88.--Same along the 180th meridian, stations 24-29.



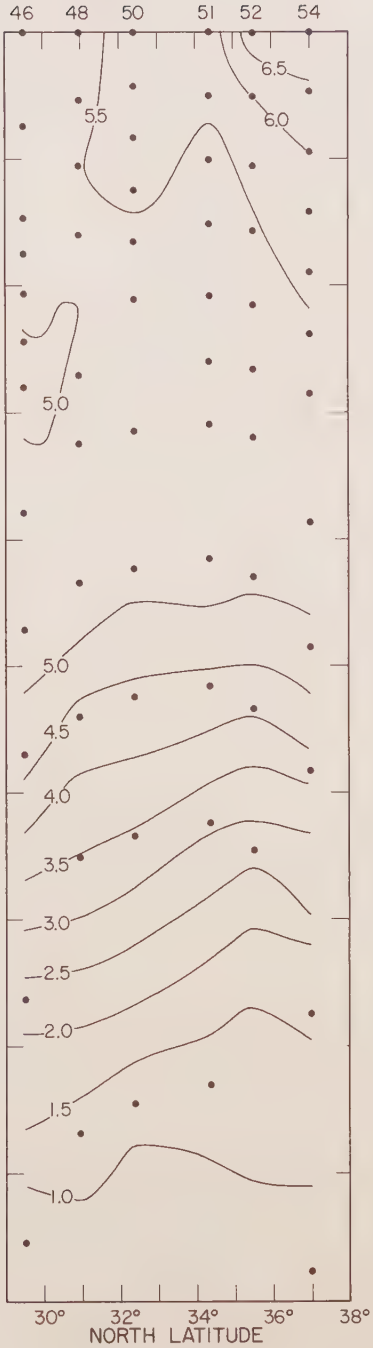


Figure 89.--Vertical section of dissolved oxygen in milliliters per liter along 172°W. longitude; Hugh M. Smith cruise 27, stations 33-44, January-February 1955. Contour interval 0.5 ml. /l.

Figure 90.--Same along 167°W. longitude, stations 46-54.

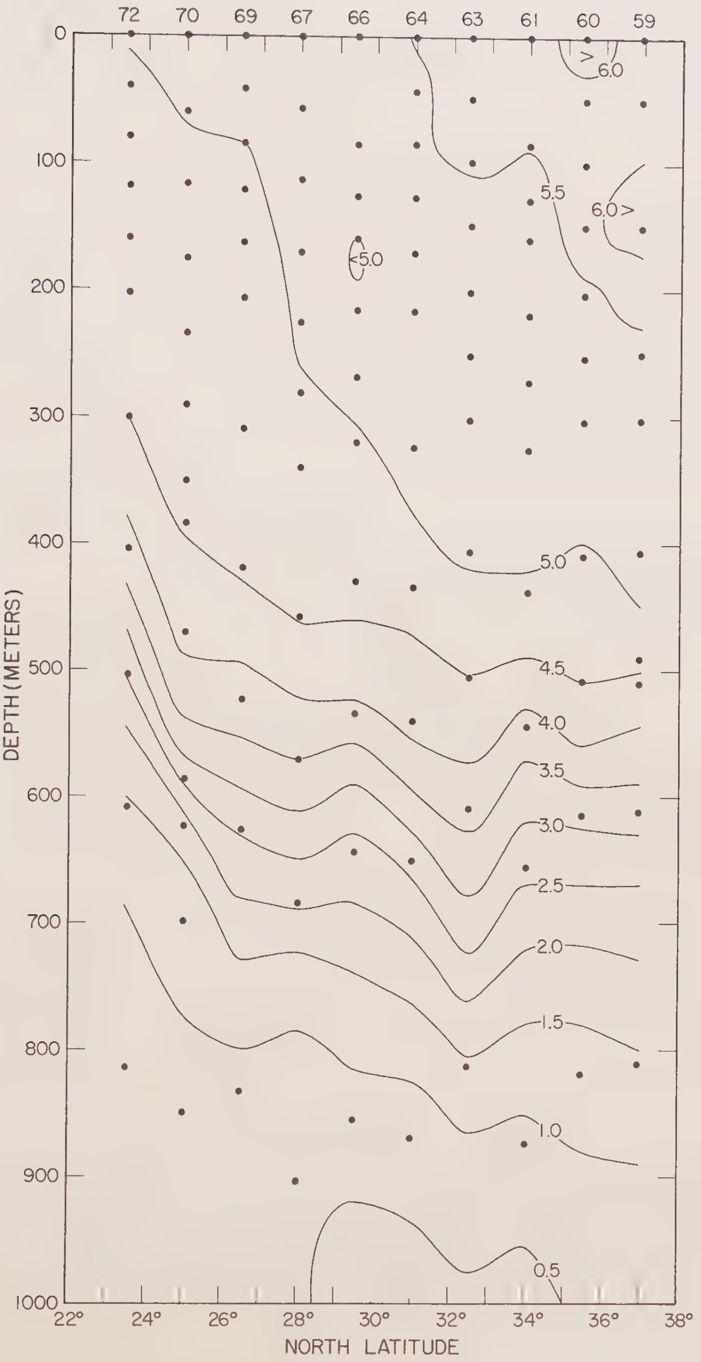


Figure 91.--Vertical section of dissolved oxygen in milliliters per liter along 159°W. longitude; Hugh M. Smith cruise 27, stations 59-72, January-February 1955. Contour interval 0.5 ml./l.

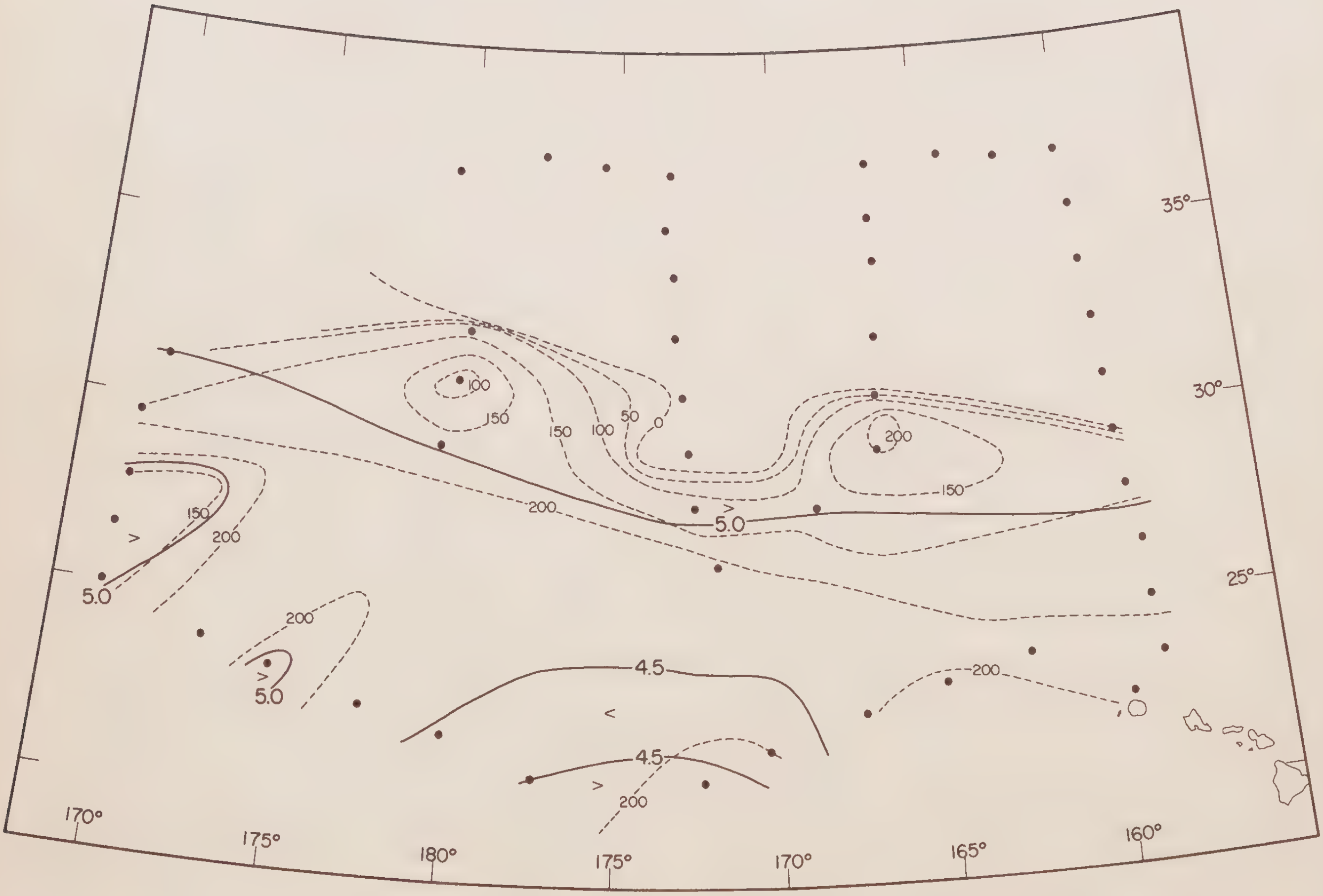

35°
30°
25°
170°
175°
180°
175°
170°
165°
160°
100
150
150
100
50
0
200
150
200
150
200
5.0
5.0
5.0
200
4.5
200
4.5
200

Figure 92.--Dissolved oxygen in milliliters per liter (solid lines) on the 25.2 sigma-t surface (depth in meters, dotted lines); Hugh M. Smith cruise 27, January-February 1955. Contour intervals: dissolved oxygen 0.5 ml./l., depth of sigma-t surface 50 m. Dots indicate station positions.

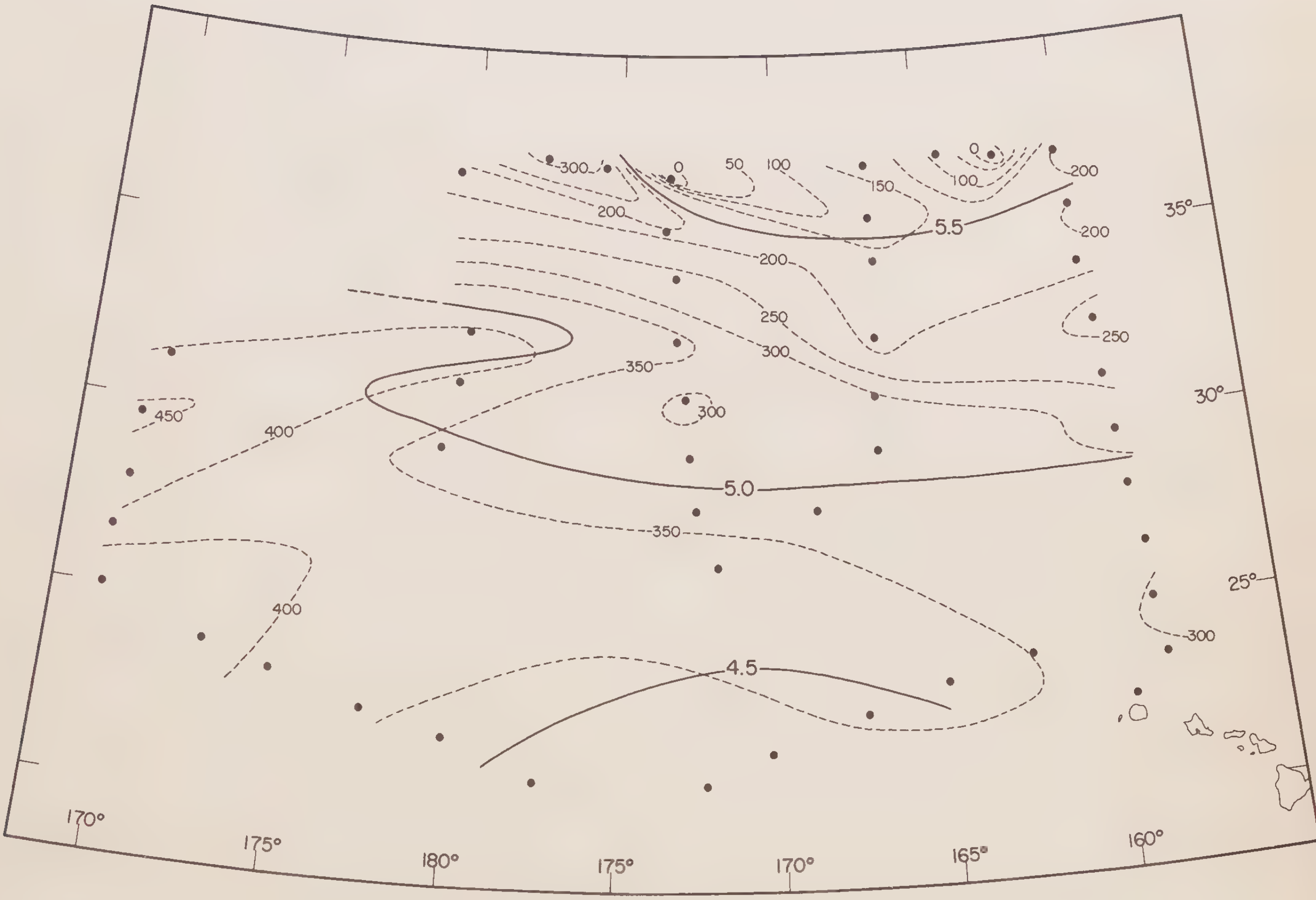

300
0
50
100
150
0
100
200
200
5.5
200
35°
200
250
250
300
350
30°
450
400
300
5.0
350
25°
400
300
4.5
170°
175°
180°
175°
170°
165°
160°

Figure 93.--Dissolved oxygen in milliliters per liter (solid lines) on the 26.0 sigma-t surface (depth in meters, dotted lines); *Hugh M. Smith* cruise 27, January-February 1955. Contour intervals: dissolved oxygen 0.5 ml./l., depth of sigma-t surface 50 m. Dots indicate station positions.

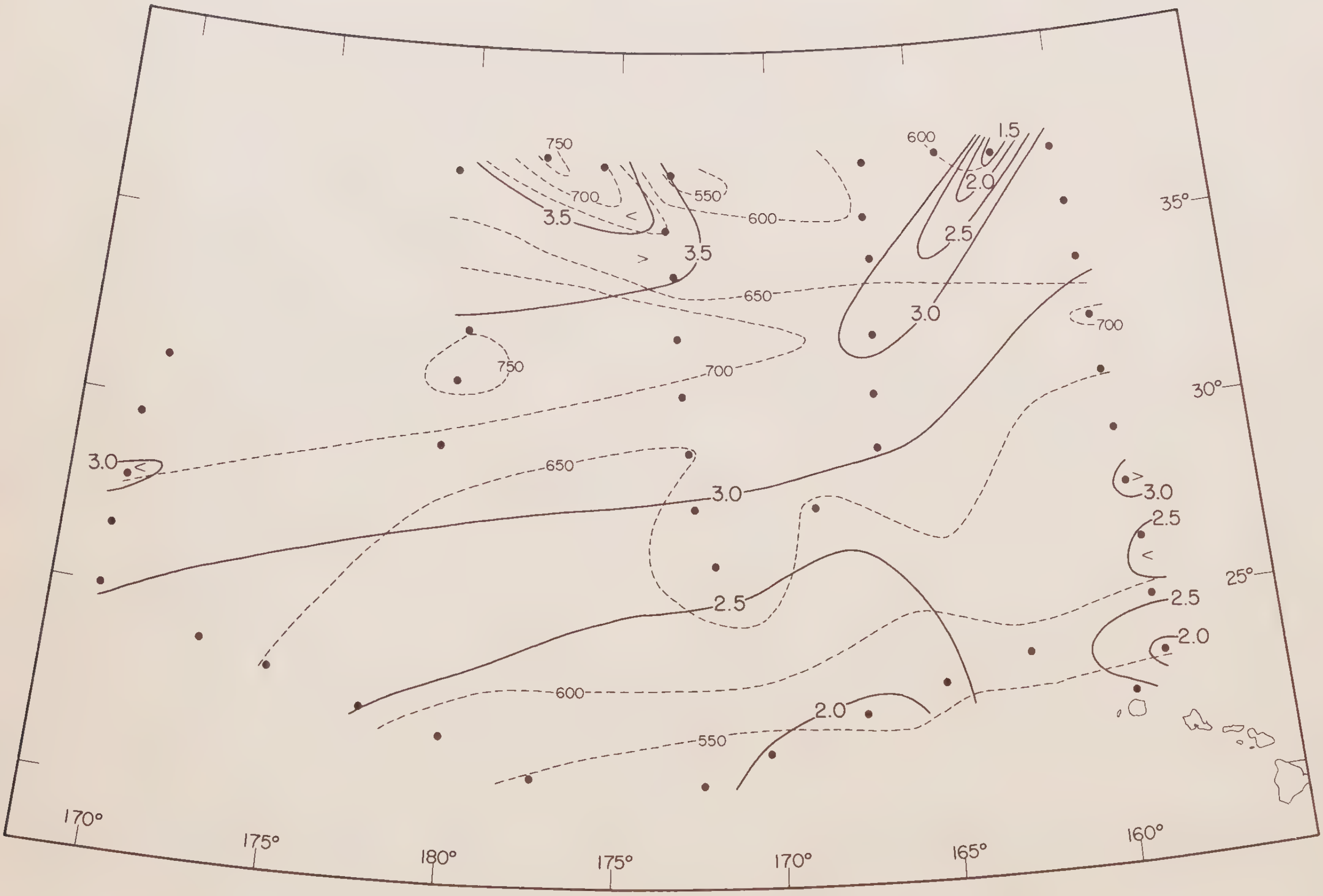

750
700
3.5
550
600
3.5
650
600
1.5
2.0
2.5
3.0
35°
700
750
700
30°
3.0
650
3.0
3.0
2.5
2.5
25°
2.5
2.0
600
2.0
550
170°
175°
180°
175°
170°
165°
160°

Figure 94.--Dissolved oxygen in milliliters per liter (solid lines) on the 26.8 sigma-t surface (depth in meters, dotted lines); Hugh M. Smith cruise 27, January-February 1955. Contour intervals: dissolved oxygen 0.5 ml./l., depth of sigma-t surface 50 m. Dots indicate station positions.

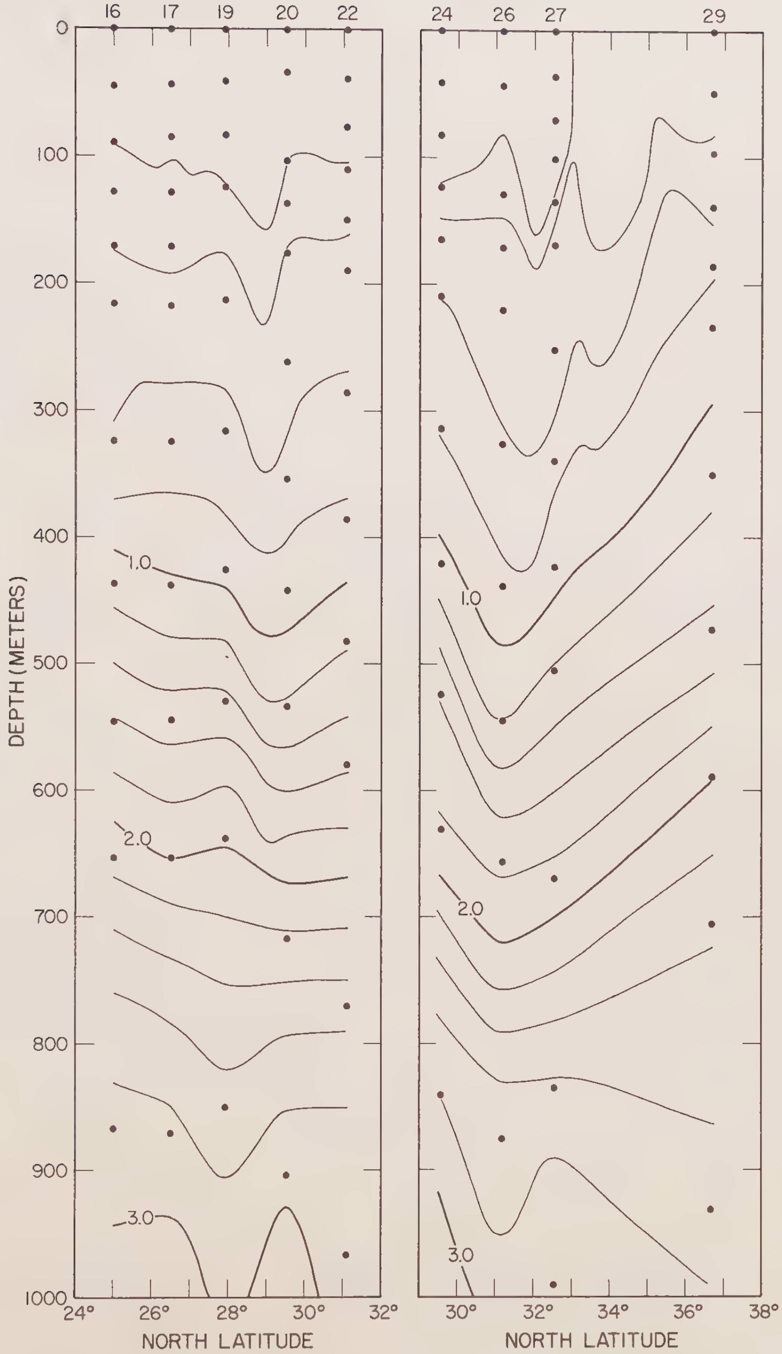
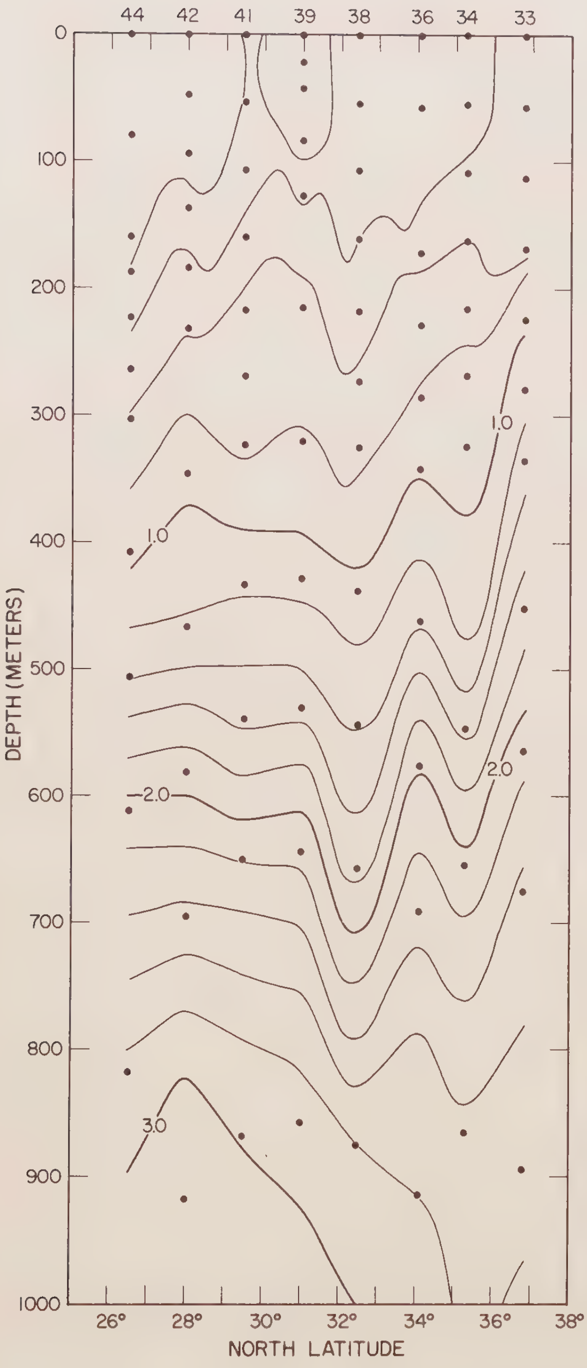


Figure 95.--Vertical section of inorganic phosphate in microgram-atoms per liter along 170°E. longitude, Hugh M. Smith cruise 27, stations 16-22, January-February 1955. Contour interval 0.2 µg at./l.

Figure 96.--Same along the 180th meridian, stations 24-29.



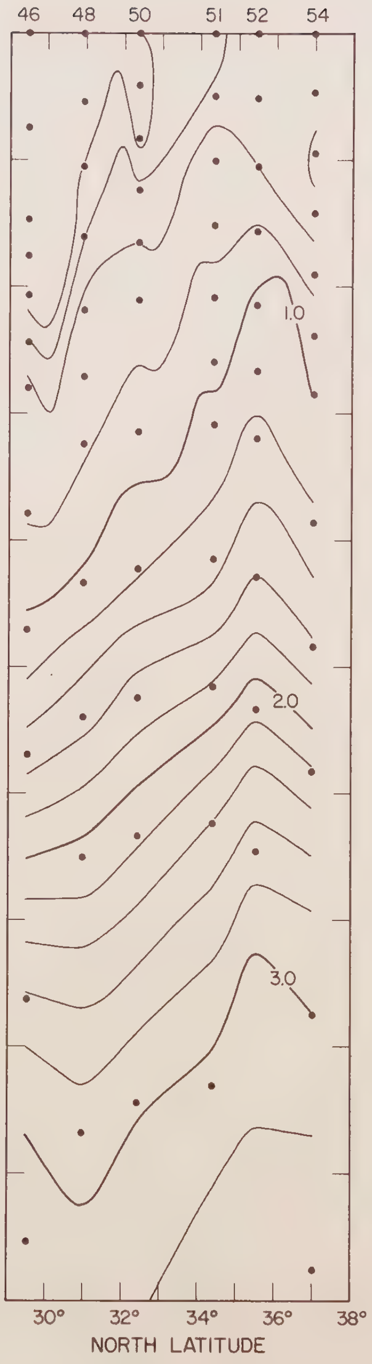


Figure 97.--Vertical section of inorganic phosphate in microgram-atoms per liter along 172°W. longitude, Hugh M. Smith cruise 27, stations 33-44, January-February 1955. Contour interval 0.2 μg at./l.

Figure 98.--Same along 167°W. longitude, stations 46-54.

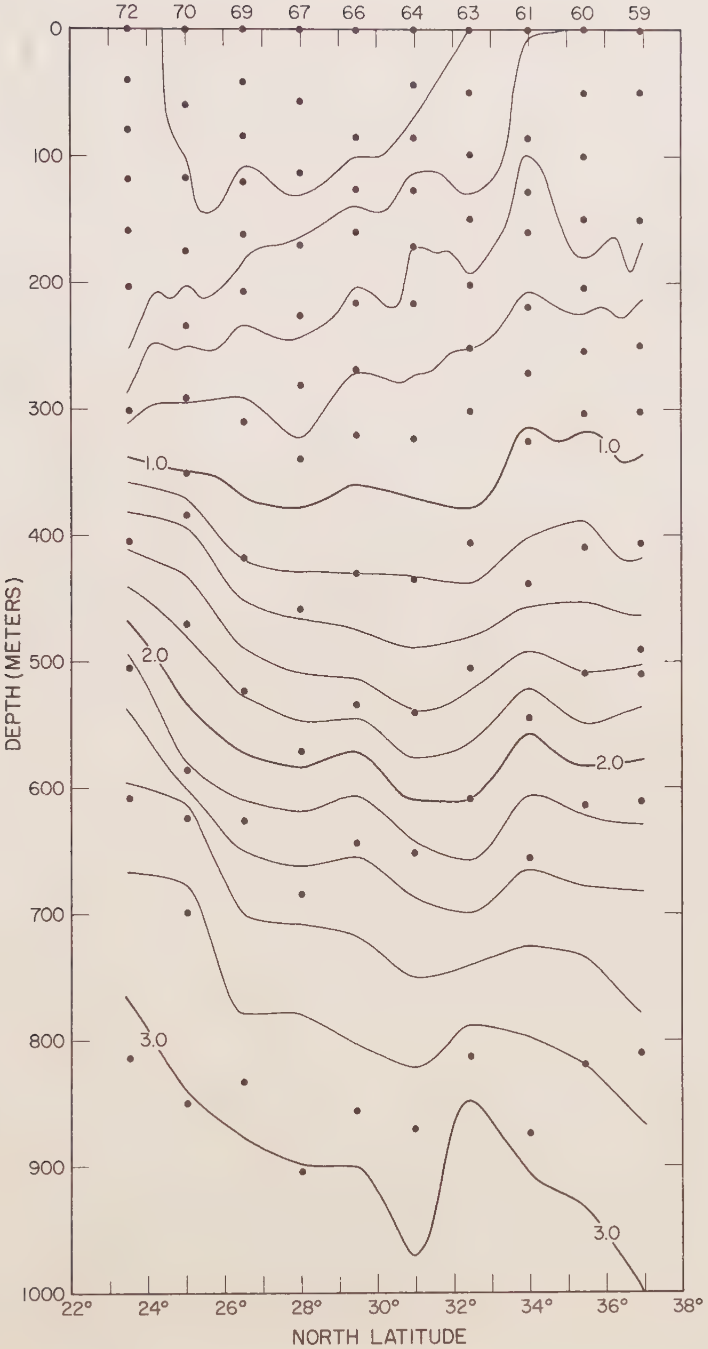


Figure 99.--Vertical section of inorganic phosphate in microgram-atoms per liter along 159°W. longitude, Hugh M. Smith cruise 27, stations 59-72, January-February 1955. Contour interval 0.2 µg at./1.

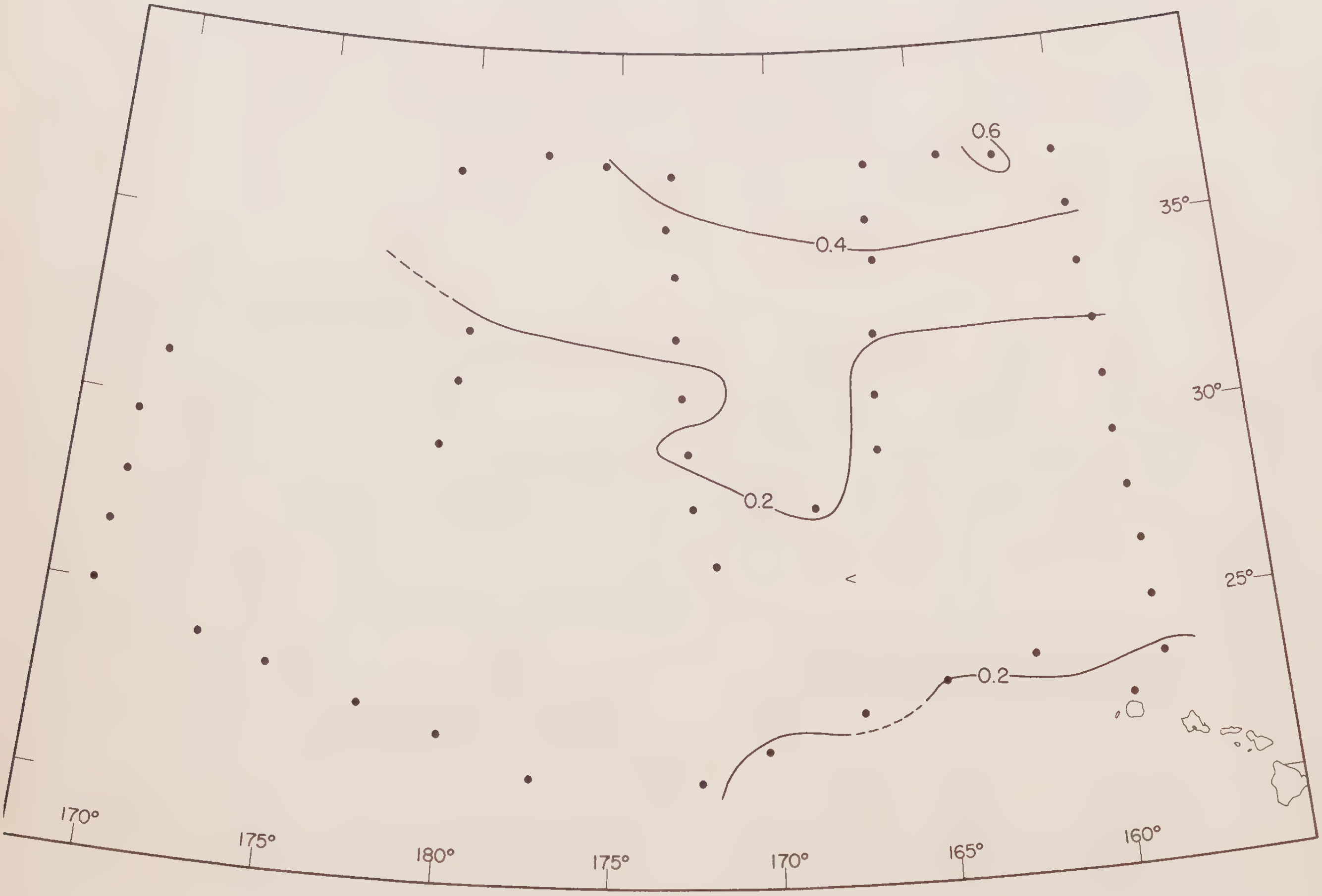

0.6
0.4
0.2
0.2
35°
30°
25°
170°
175°
180°
175°
170°
165°
160°

Figure 100. --Surface inorganic phosphate in microgram-atoms per liter; Hugh M. Smith cruise 27, January-February 1955. Contour interval 0.2 µg at./l. Dots indicate observed values.

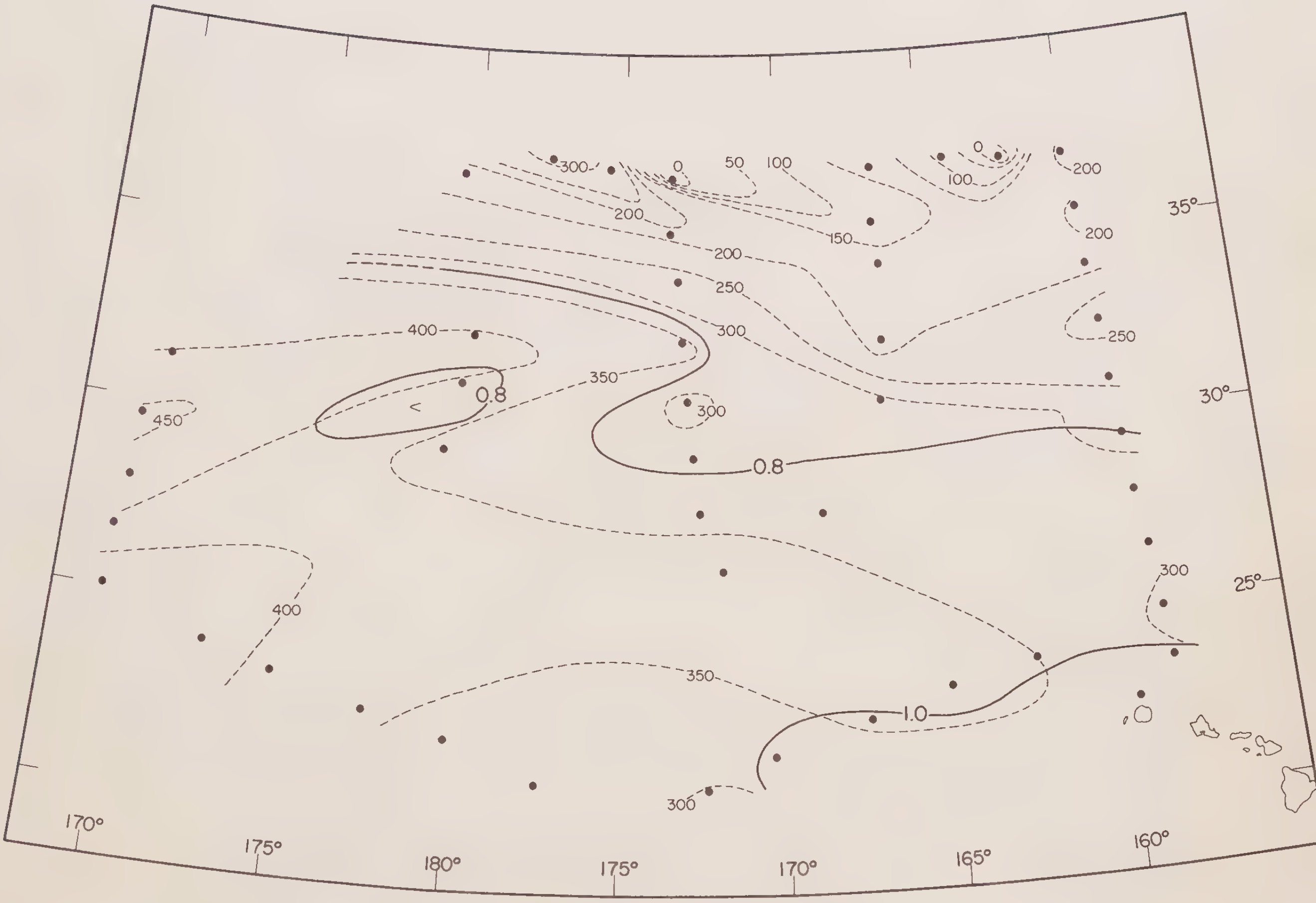

300
0
50
100
0
100
200
200
150
200
200
250
300
250
400
350
0.8
450
300
0.8
300
400
350
1.0
300
35°
30°
25°
170°
175°
180°
175°
170°
165°
160°

Figure 101.--Inorganic phosphate in microgram-atoms per liter (solid lines) on the 26.0 sigma-t surface (depth in meters, dotted lines); Hugh M. Smith cruise 27, January-February 1955. Contour intervals: inorganic phosphate 0.2 µg at./l., depth of sigma-t surface 50 m. Dots indicate station positions.

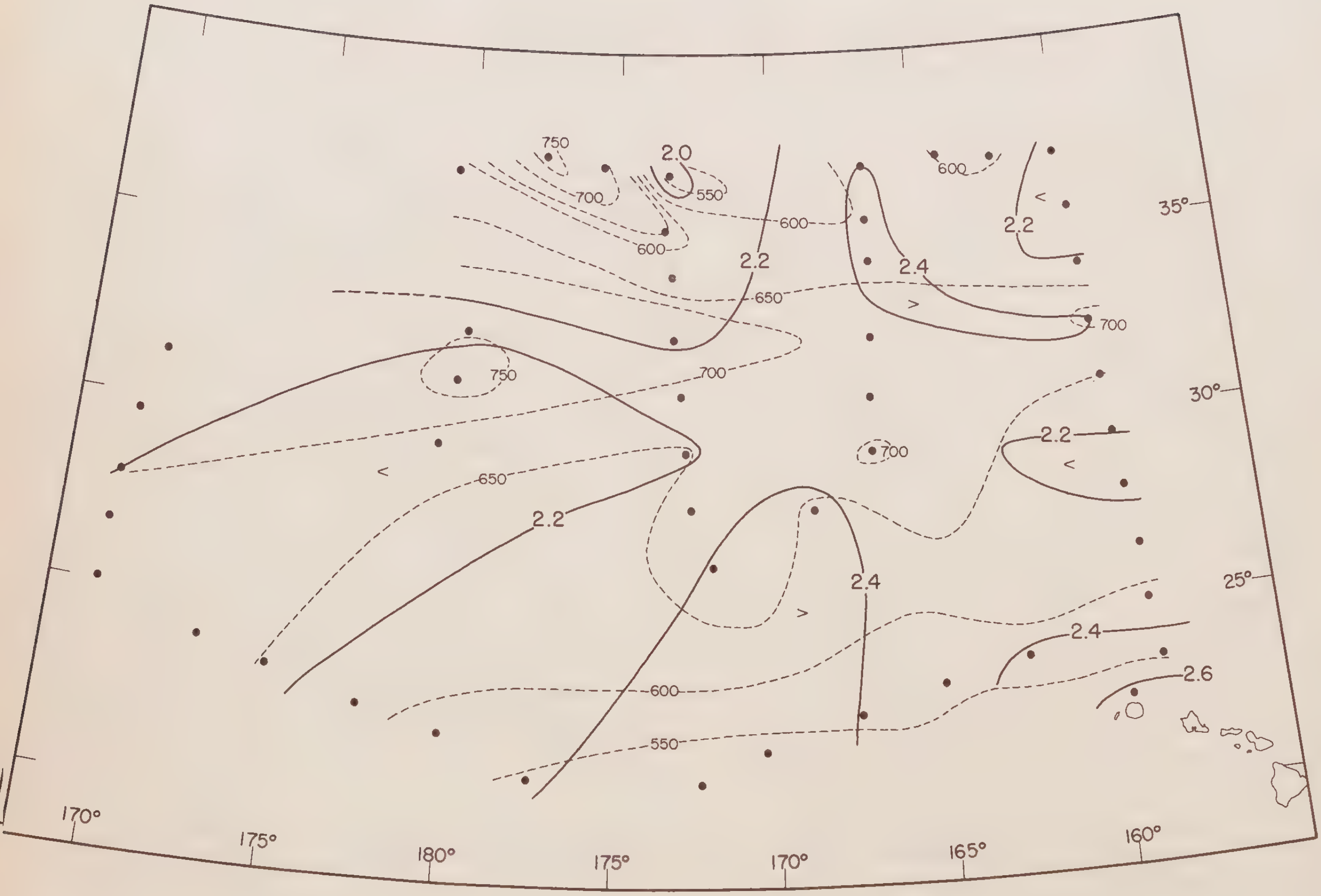

750
2.0
700
550
600
600
2.2
600
2.4
2.2
<
650
>
700
35°
750
700
30°
2.2
700
650
<
<
2.2
2.4
>
25°
2.4
2.6
600
550
170°
175°
180°
175°
170°
165°
160°

Figure 102.--Inorganic phosphate in microgram-atoms per liter (solid lines) on the 26.8 sigma-t surface (depth in meters, dotted lines); Hugh M. Smith cruise 27, January-February 1955. Contour intervals: inorganic phosphate 0.2 µg at./l., depth of sigma-t surface 50 m. Dots indicate station positions.

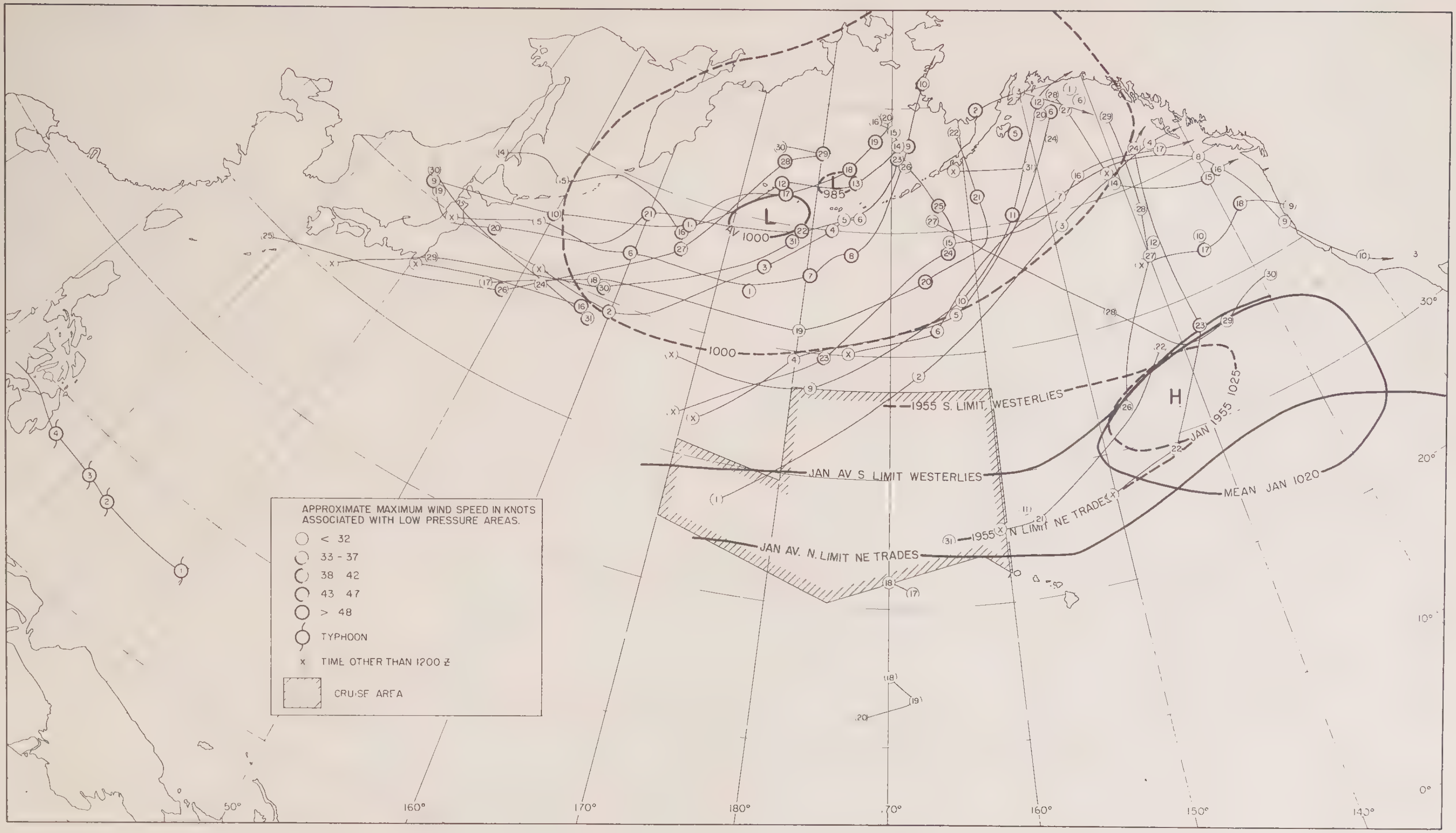

APPROXIMATE MAXIMUM WIND SPEED IN KNOTS ASSOCIATED WITH LOW PRESSURE AREAS.
< 32
33 - 37
38 42
43 47
> 48
TYPHOON
x TIME OTHER THAN 1200 Z
CRUISE AREA
L
AV 1000
L
985
1000
H
JAN 1955 1025
MEAN JAN 1020
1955 S. LIMIT WESTERLIES
JAN AV S LIMIT WESTERLIES
1955 N LIMIT NE TRADES
JAN AV. N. LIMIT NE TRADES
30°
20°
10°
0°
50°
160°
170°
180°
170°
160°
150°
140°

Figure 103.--Normal (heavy solid lines) and mean January 1955 (broken lines) position of the Aleutian Low and Eastern North Pacific High; normal and 1954 mean monthly limits of northeast trades and westerlies; tracks of centers of low pressure areas, showing daily positions.

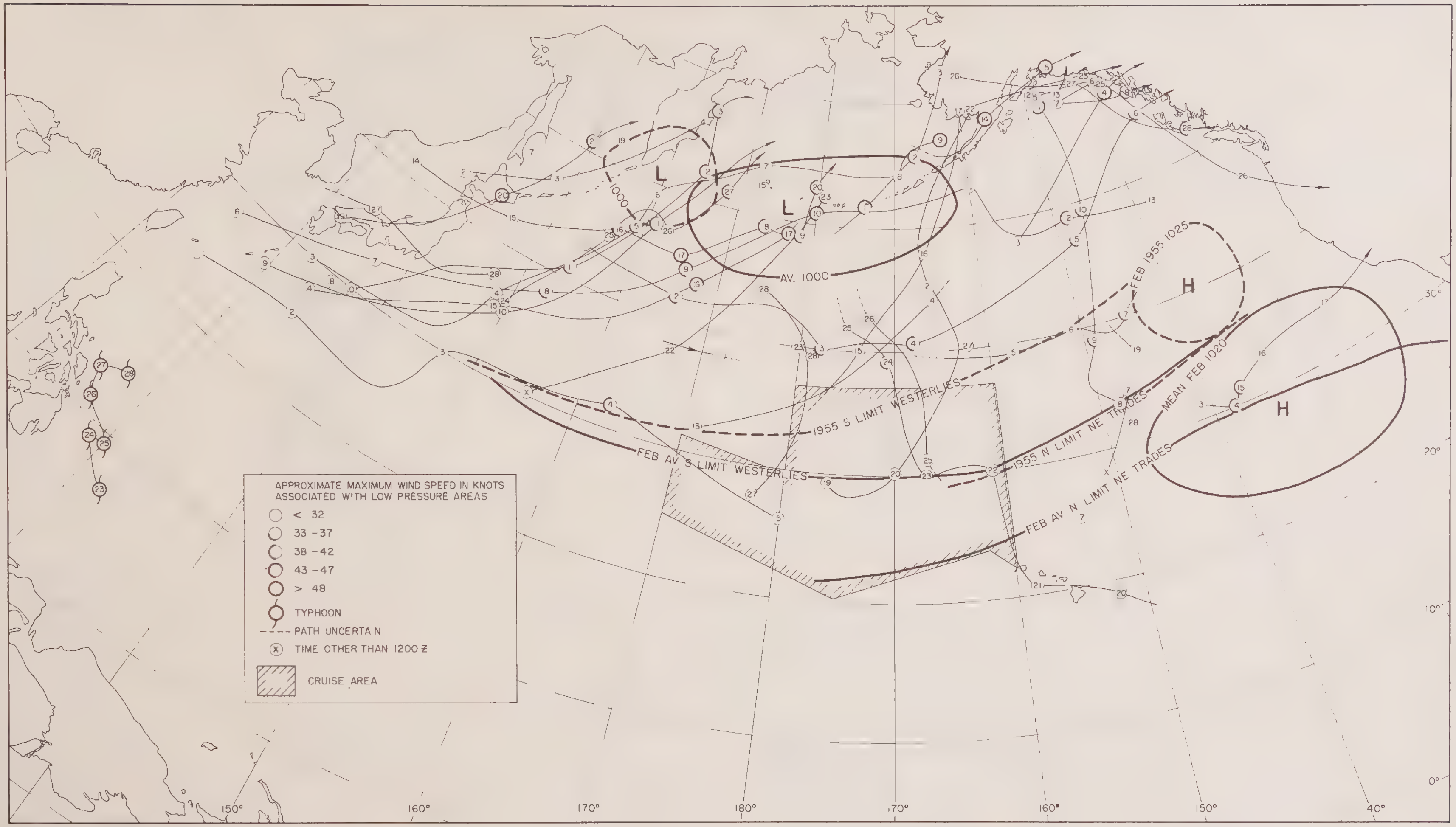

APPROXIMATE MAXIMUM WIND SPEED IN KNOTS ASSOCIATED WITH LOW PRESSURE AREAS
< 32
33 -37
38 -42
43 -47
> 48
TYPHOON
PATH UNCERTAIN
TIME OTHER THAN 1200 Z
CRUISE AREA
L
L
H
H
1000
AV. 1000
FEB 1955 1025
MEAN FEB 1020
1955 S LIMIT WESTERLIES
FEB AV S LIMIT WESTERLIES
1955 N LIMIT NE TRADES
FEB AV N LIMIT NE TRADES
150°
160°
170°
180°
170°
160°
150°
140°
30°
20°
10°
0°

Figure 104.--Normal (heavy solid lines) and mean February 1955 (broken lines) position of the Aleutian Low and Eastern North Pacific High; normal and 1954 mean monthly limits of northeast trades and westerlies; tracks of centers of low pressure areas, showing daily positions.

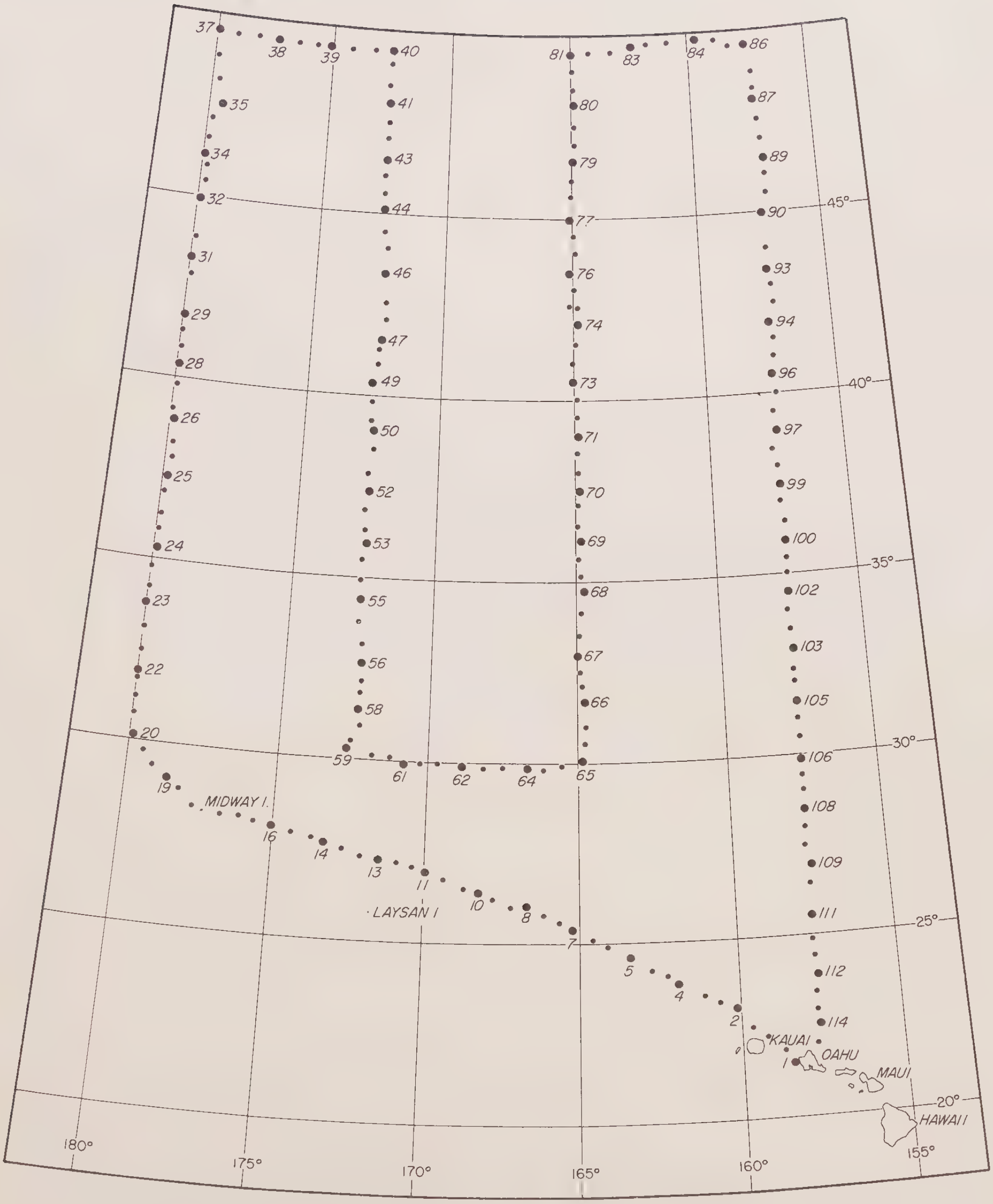

37
38
39
40
81
83
84
86
35
41
80
87
34
43
79
89
32
44
77
90
45°
31
46
76
93
29
74
94
47
28
49
73
96
40°
26
50
71
97
25
52
70
99
24
53
69
100
35°
23
55
68
102
67
103
22
56
66
105
58
20
59
61
62
64
65
106
30°
19
MIDWAY I.
16
14
13
11
108
109
LAYSAN I
10
8
111
25°
7
5
112
4
2
114
KAUAI
OAHU
1
MAUI
20°
HAWAII
180°
175°
170°
165°
160°
155°

Figure 105.--Oceanographic station positions; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Larged numbered dots indicate oceanographic stations. Small dots indicate positions of BT lowerings between stations.

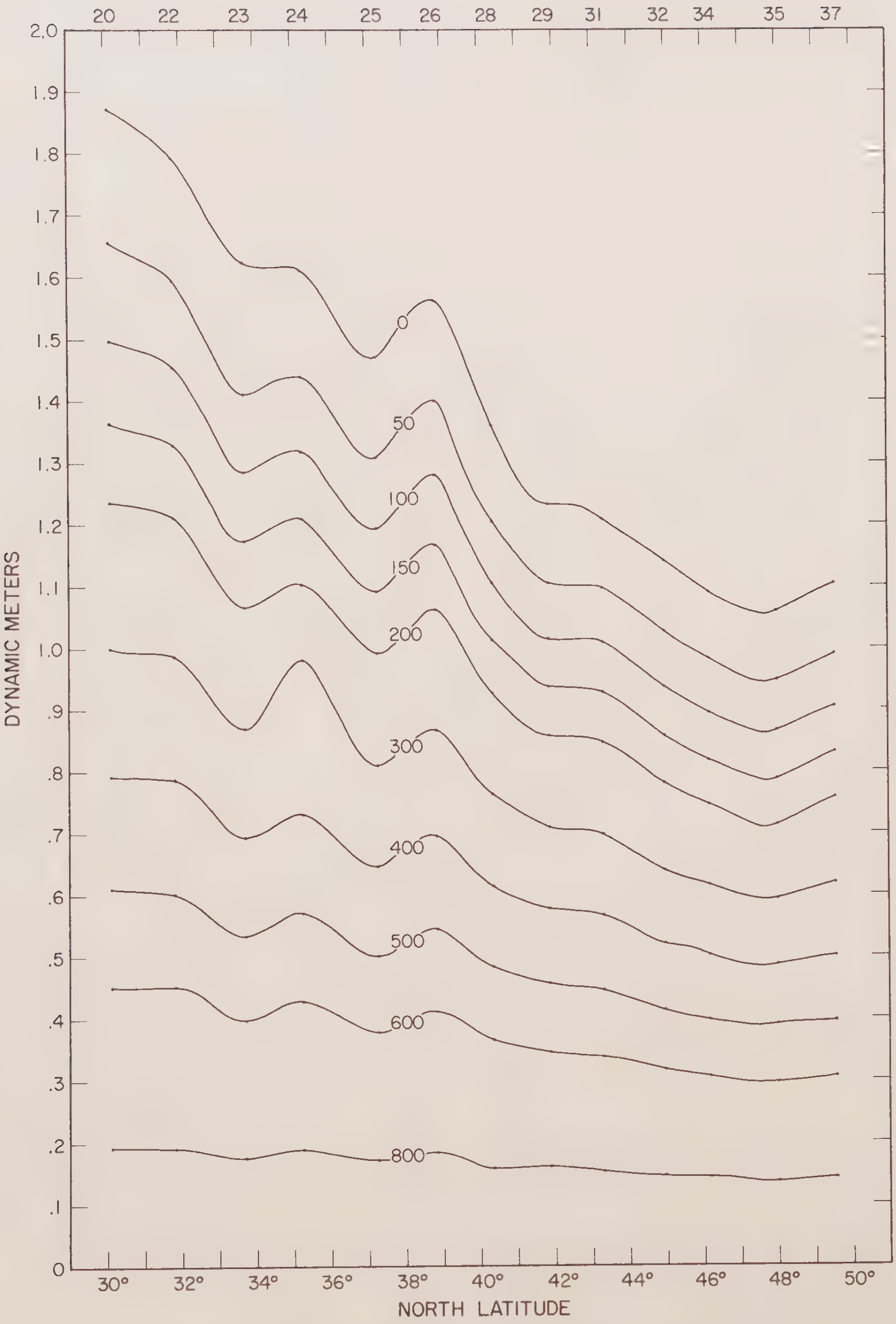


Figure 106.--Smoothed geopotential anomaly of the isobaric surfaces in dynamic meters relative to the 1,000-db. surface, neglecting pressure terms in the specific volume anomaly, along the 180th meridian; Hugh M. Smith cruise 30 (NORPAC), stations 20-37, July-August 1955. Points represent computed values.

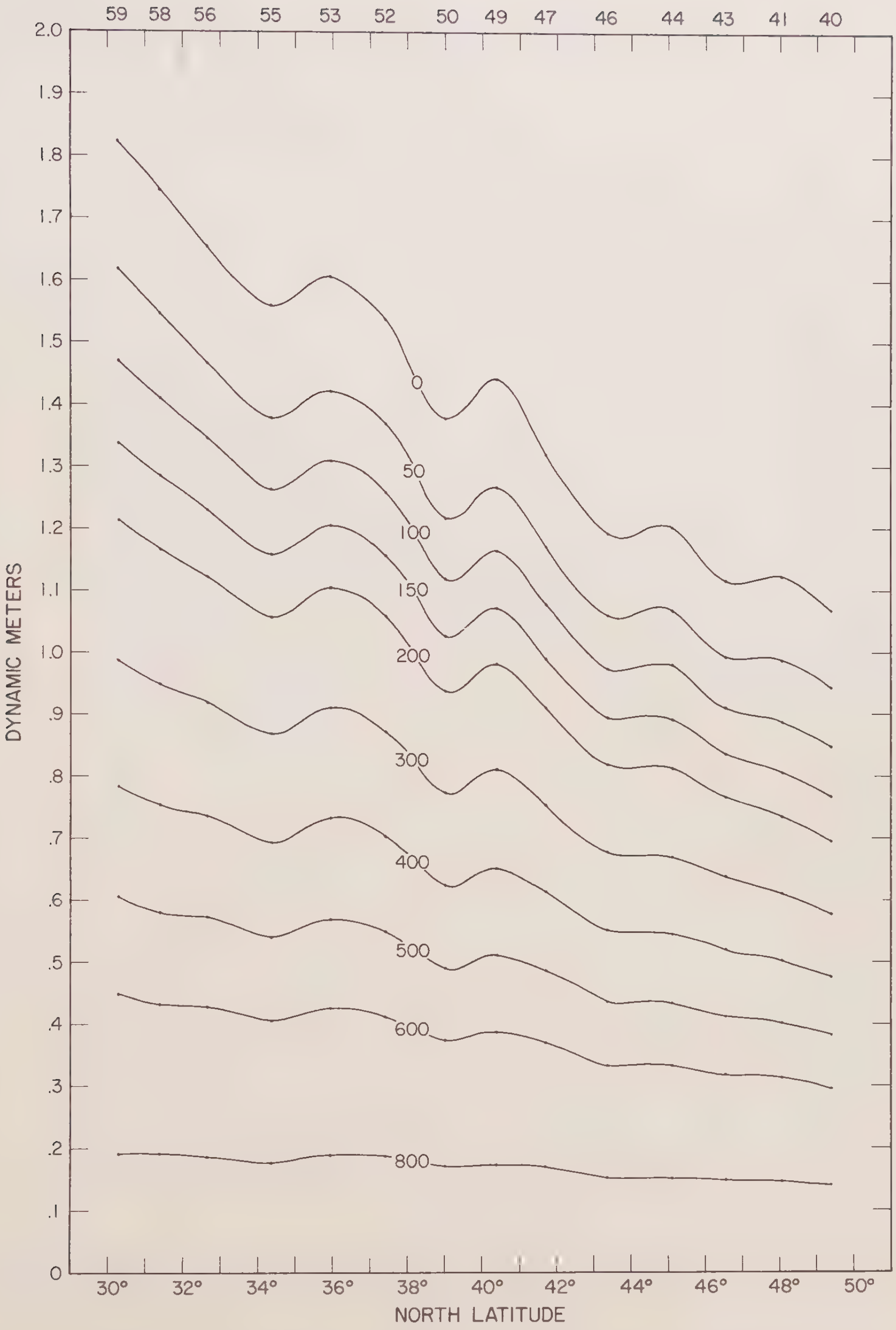


Figure 107.--Smoothed geopotential anomaly of the isobaric surfaces in dynamic meters relative to the 1,000-db. surface, neglecting pressure terms in the specific volume anomaly, along 172°30'W. longitude; Hugh M. Smith cruise 30 (NORPAC), stations 40-59, July-August 1955. Points represent computed values.

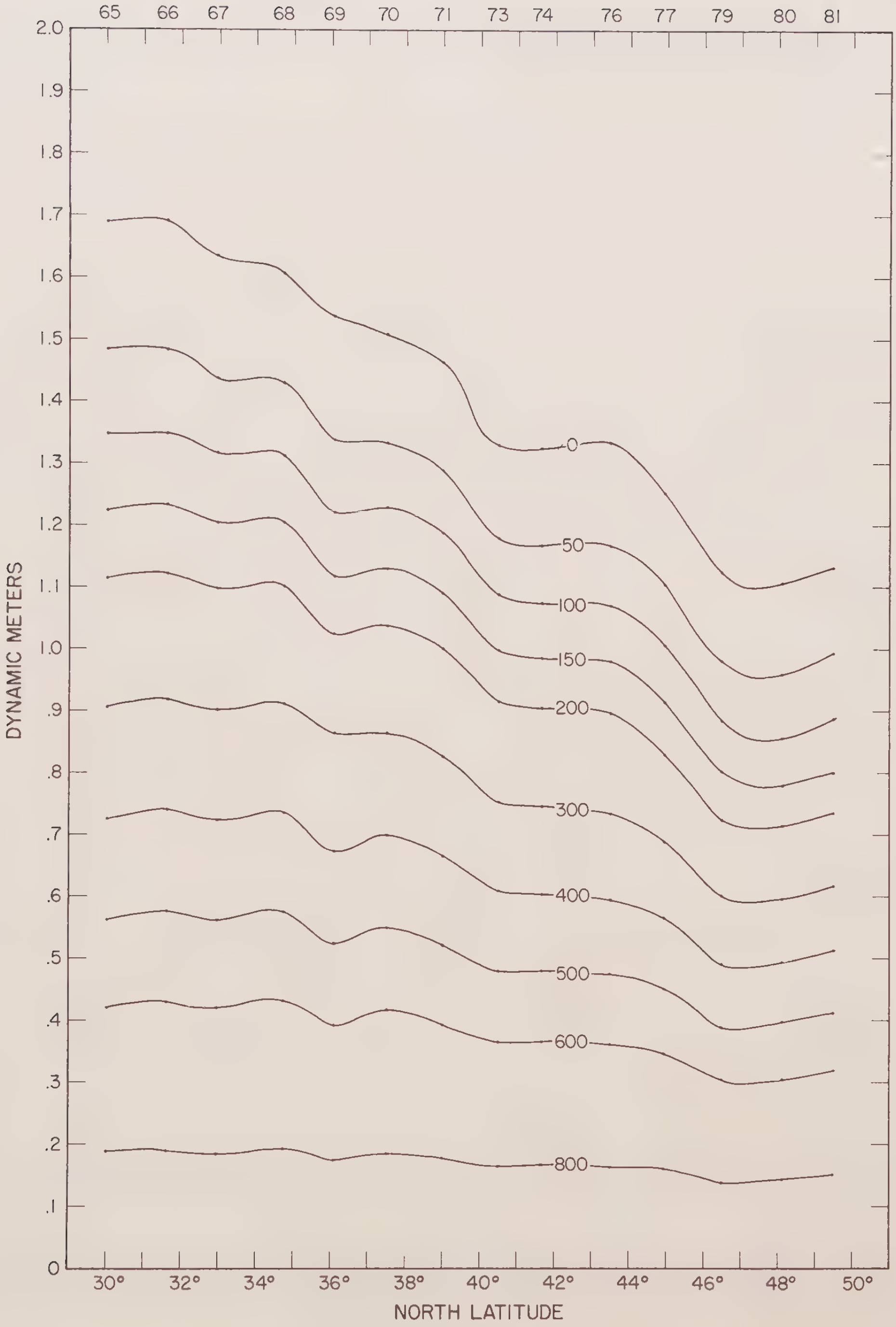


Figure 108.--Smoothed geopotential anomaly of the isobaric surfaces in dynamic meters relative to the 1,000-db. surface, neglecting pressure terms in the specific volume anomaly, along 165° W. longitude; Hugh M. Smith cruise 30 (NORPAC), stations 65-81, July-August 1955. Points represent computed values.

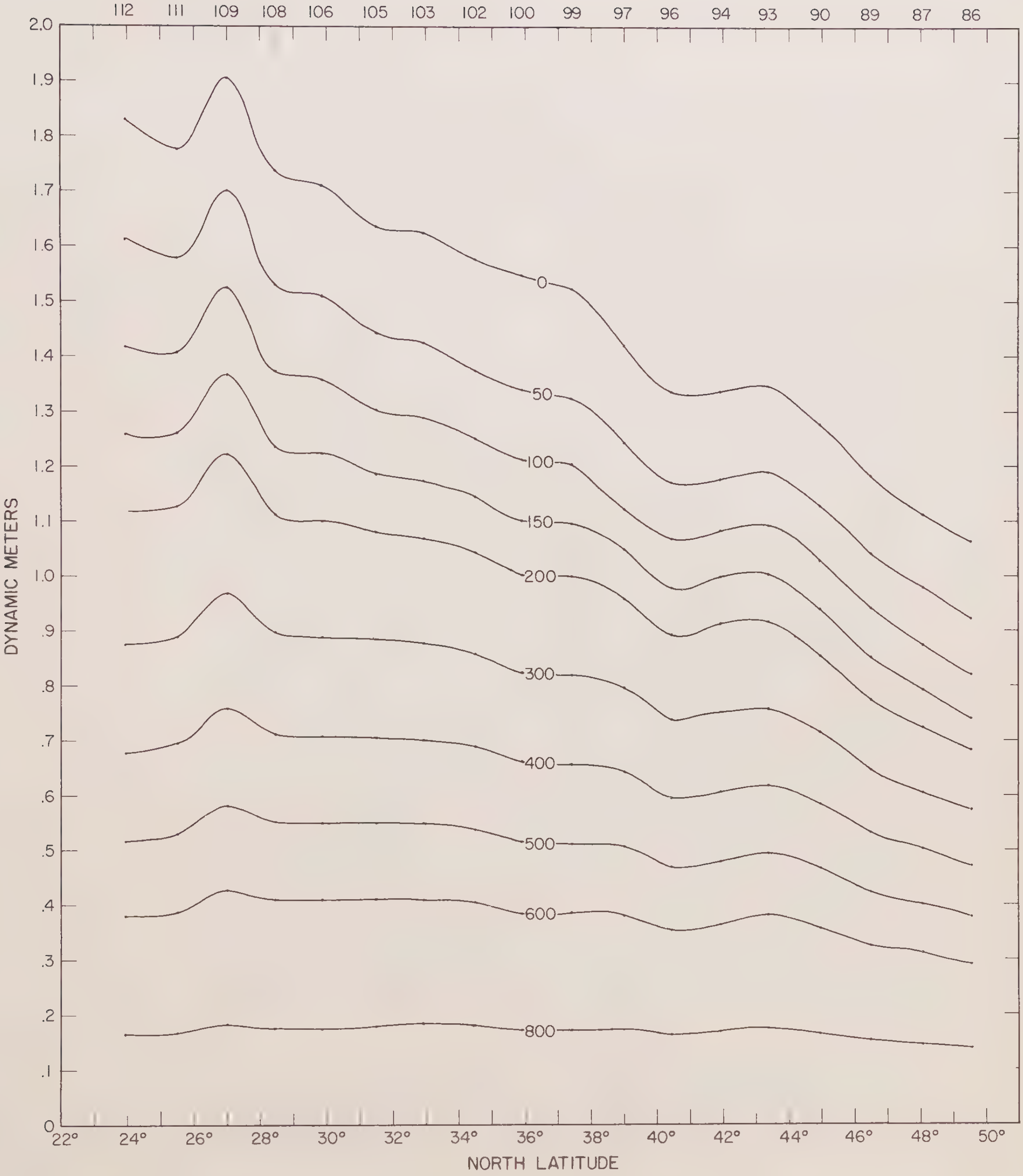


Figure 109.--Smoothed geopotential anomaly of the isobaric surfaces in dynamic meters relative to the 1,000-db. surface, neglecting pressure terms in the specific volume anomaly, along 157°30'W. longitude; Hugh M. Smith cruise 30 (NORPAC), stations 86-112, July-August 1955. Points represent computed values.

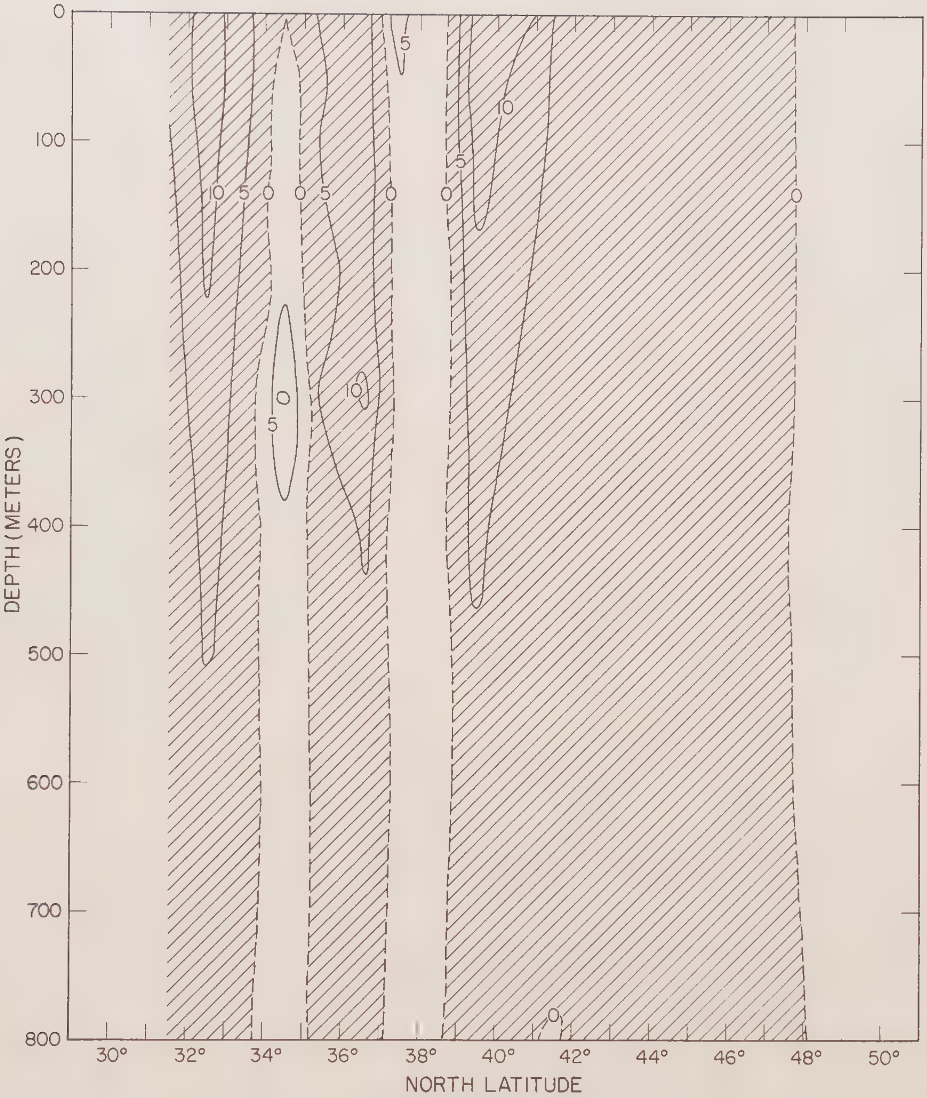


Figure 110.--Zonal components of the geostrophic currents in centimeters per second across the 180th meridian; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Hatched areas indicate easterly flow. Contour interval 5 cm./sec.

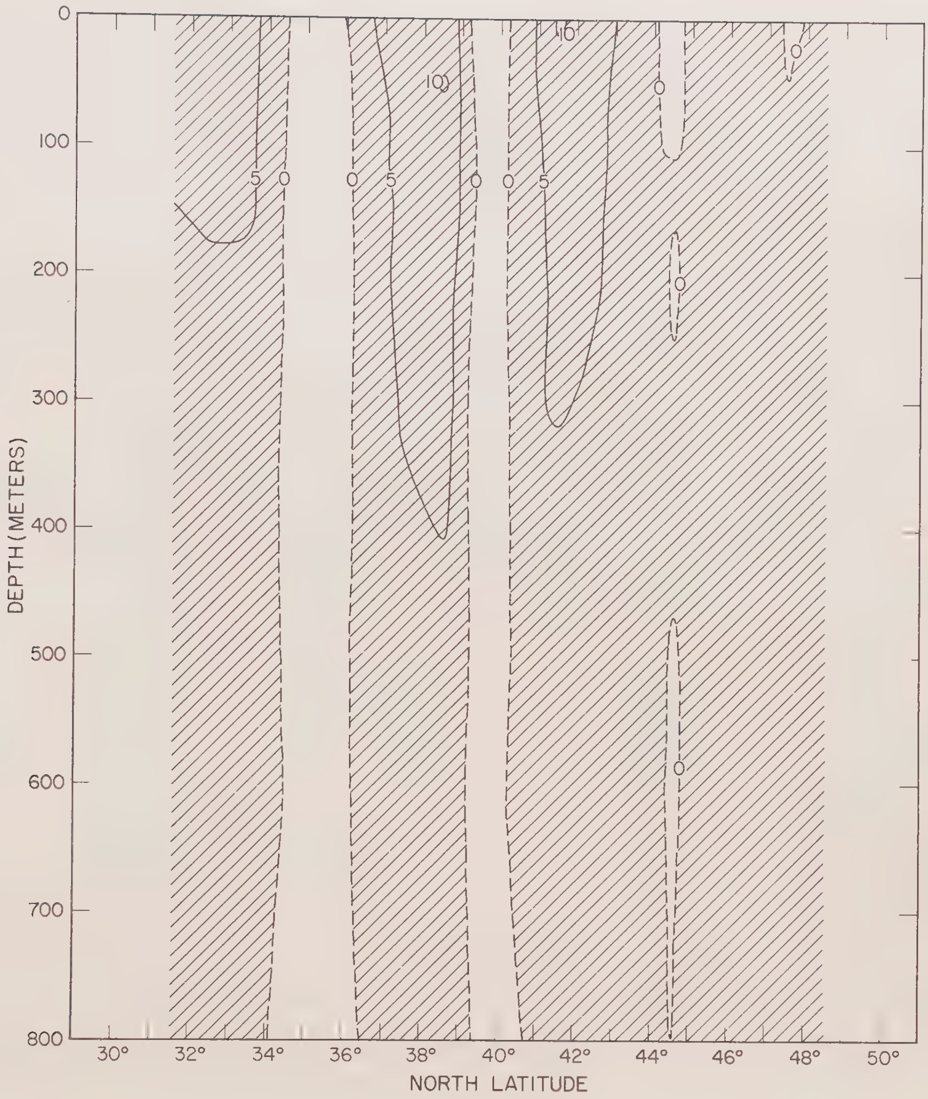


Figure 111.--Zonal components of the geostrophic currents in centimeters per second across 172° W. longitude; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Hatched areas indicate easterly flow. Contour interval 5 cm./sec.

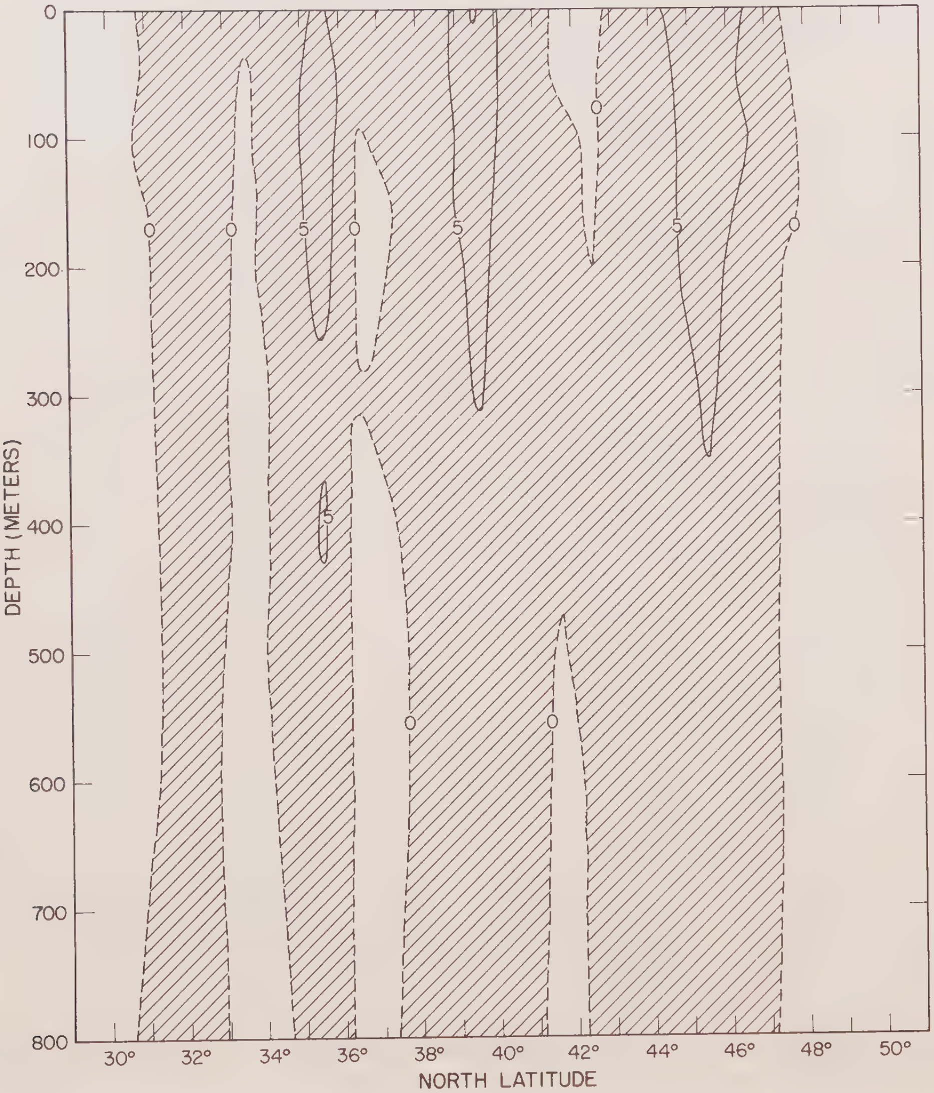


Figure 112.--Zonal components of the geostrophic currents in centimeters per second across 165°W. longitude; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Hatched areas indicate easterly flow. Contour interval 5 cm./sec.

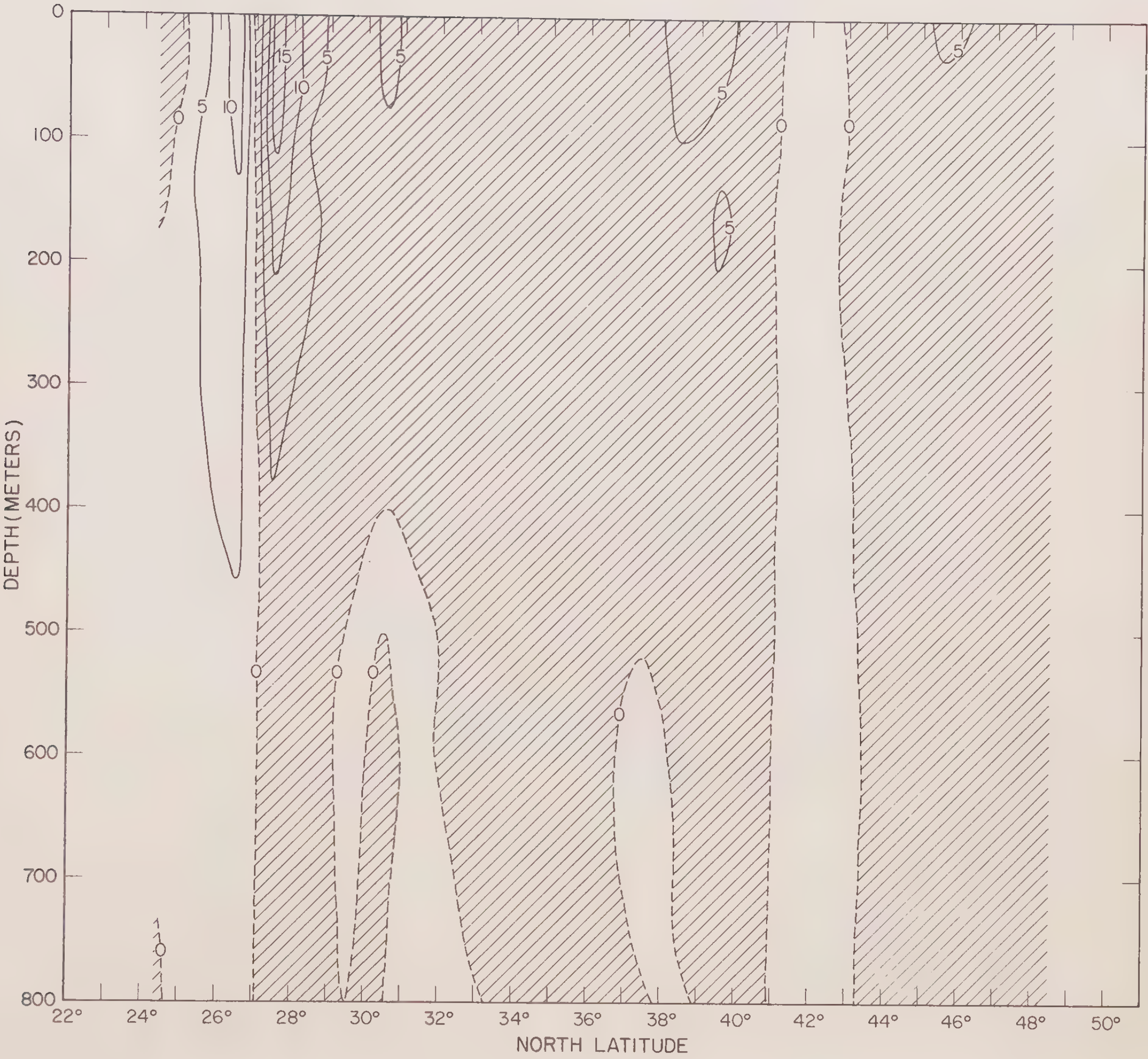


Figure 113.--Zonal components of the geostrophic currents in centimeters per second across 157°30'W. longitude; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Hatched areas indicate easterly flow. Contour interval 5 cm./sec.

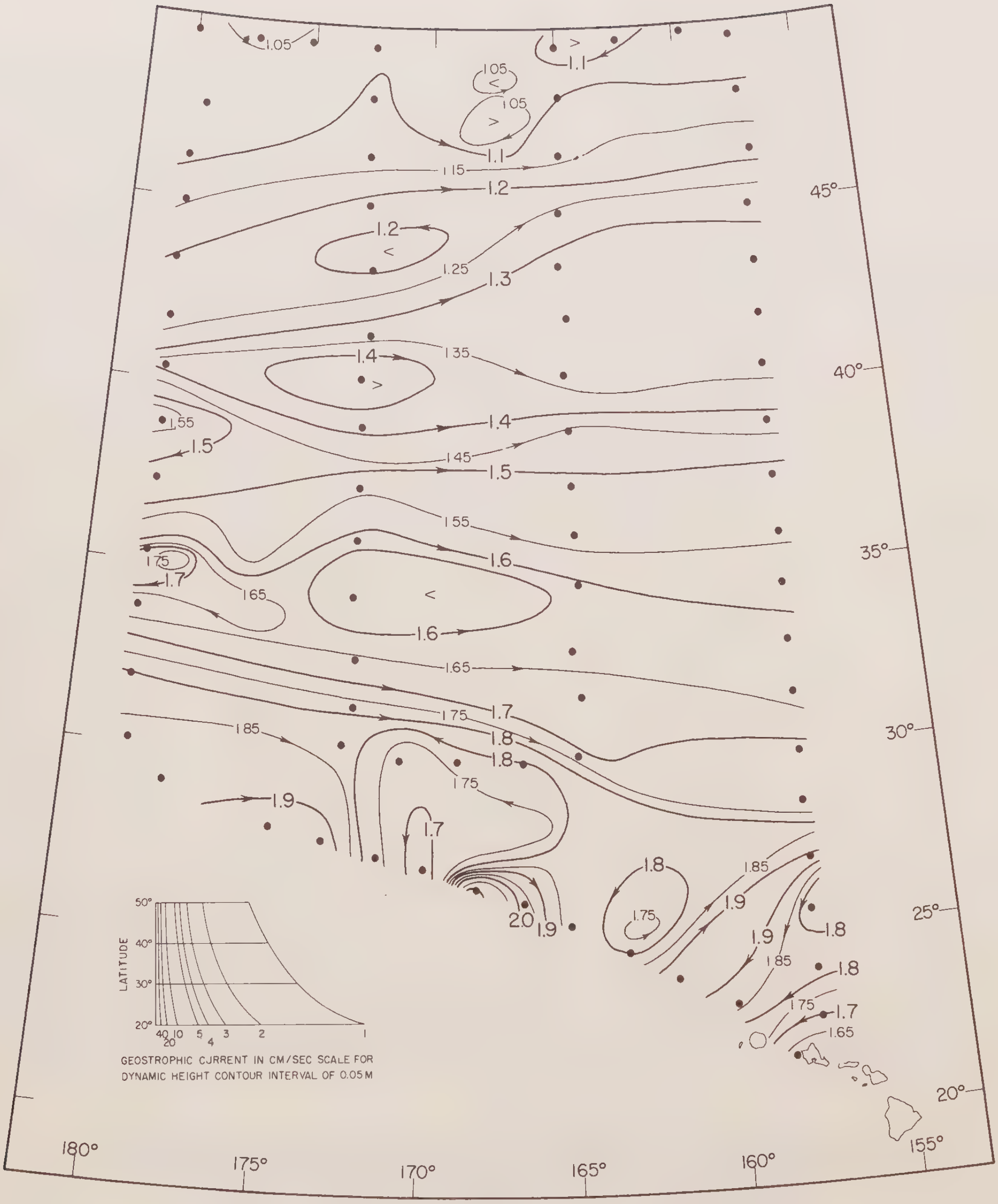

1.05
1.1
1.05
1.05
1.1
1.15
1.2
45°
1.2
1.25
1.3
1.35
1.4
40°
1.55
1.5
1.4
1.45
1.5
1.55
35°
1.6
1.75
1.7
1.65
1.6
1.65
1.75
1.7
1.8
1.8
30°
1.85
1.75
1.9
1.7
1.8
1.85
2.0
1.9
1.75
1.9
1.9
1.8
25°
1.85
1.8
1.75
1.7
1.65
20°
LATITUDE
50°
40°
30°
20°
40 10 5 3 2 1
20 4
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR DYNAMIC HEIGHT CONTOUR INTERVAL OF 0.05 M
180°
175°
170°
165°
160°
155°

Figure 114.--Anomaly of the geopotential topography of the sea surface in dynamic meters relative to the 1,000-db. surface; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.05 m.

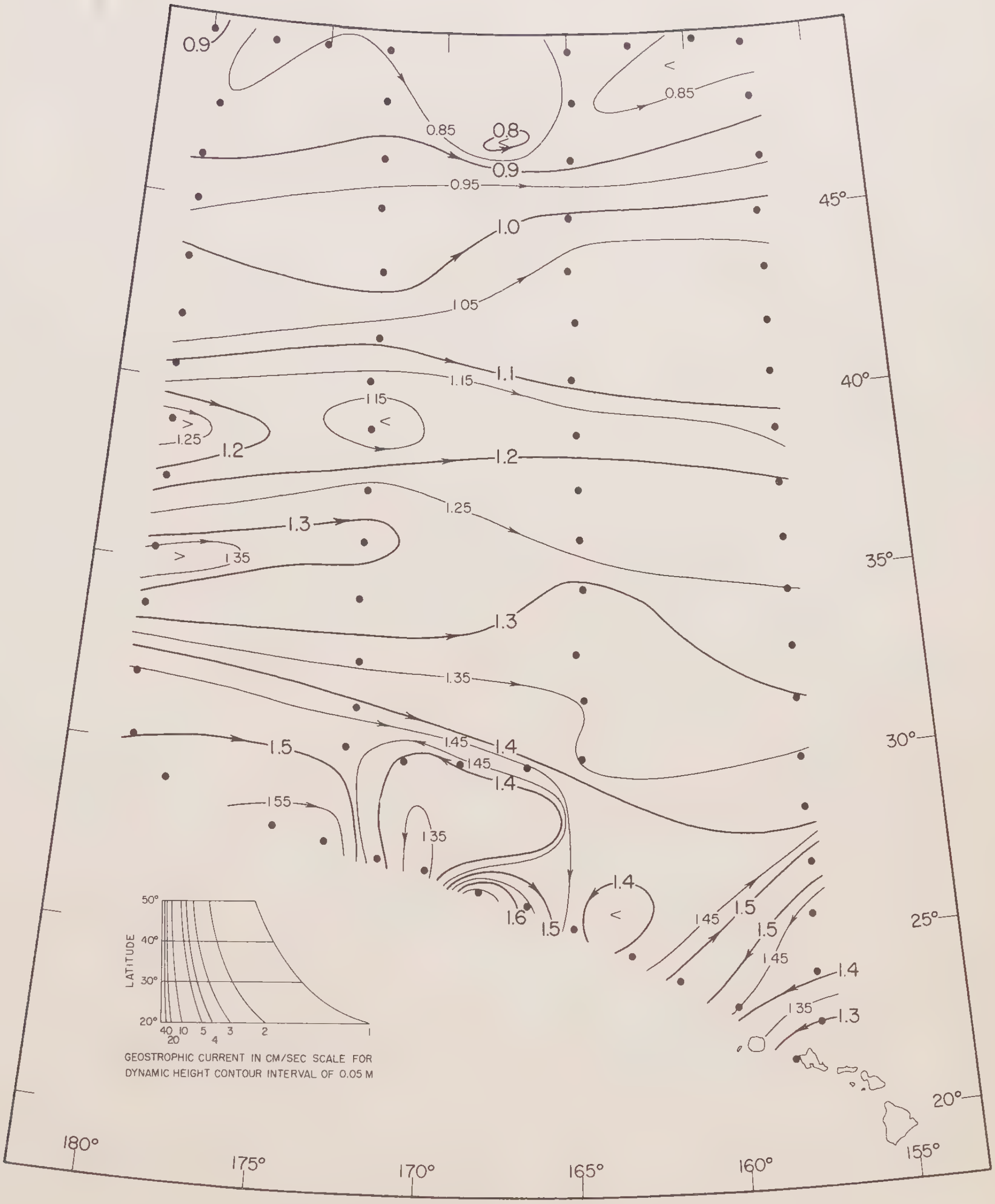

0.9
0.85
0.8
0.85
0.9
0.95
1.0
1.05
1.1
1.15
1.15
1.25
1.2
1.2
1.25
1.3
1.35
1.3
1.35
1.5
1.45
1.4
1.45
1.4
1.55
1.35
1.6
1.5
1.4
1.45
1.5
1.5
1.45
1.4
1.35
1.3
45°
40°
35°
30°
25°
20°
180°
175°
170°
165°
160°
155°
50°
40°
30°
20°
LATITUDE
40
20
10
5
4
3
2
1
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR DYNAMIC HEIGHT CONTOUR INTERVAL OF 0.05 M

Figure 115.--Anomaly of the geopotential topography of the 100-db. surface in dynamic meters relative to the 1000-db. surface; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.05 m.

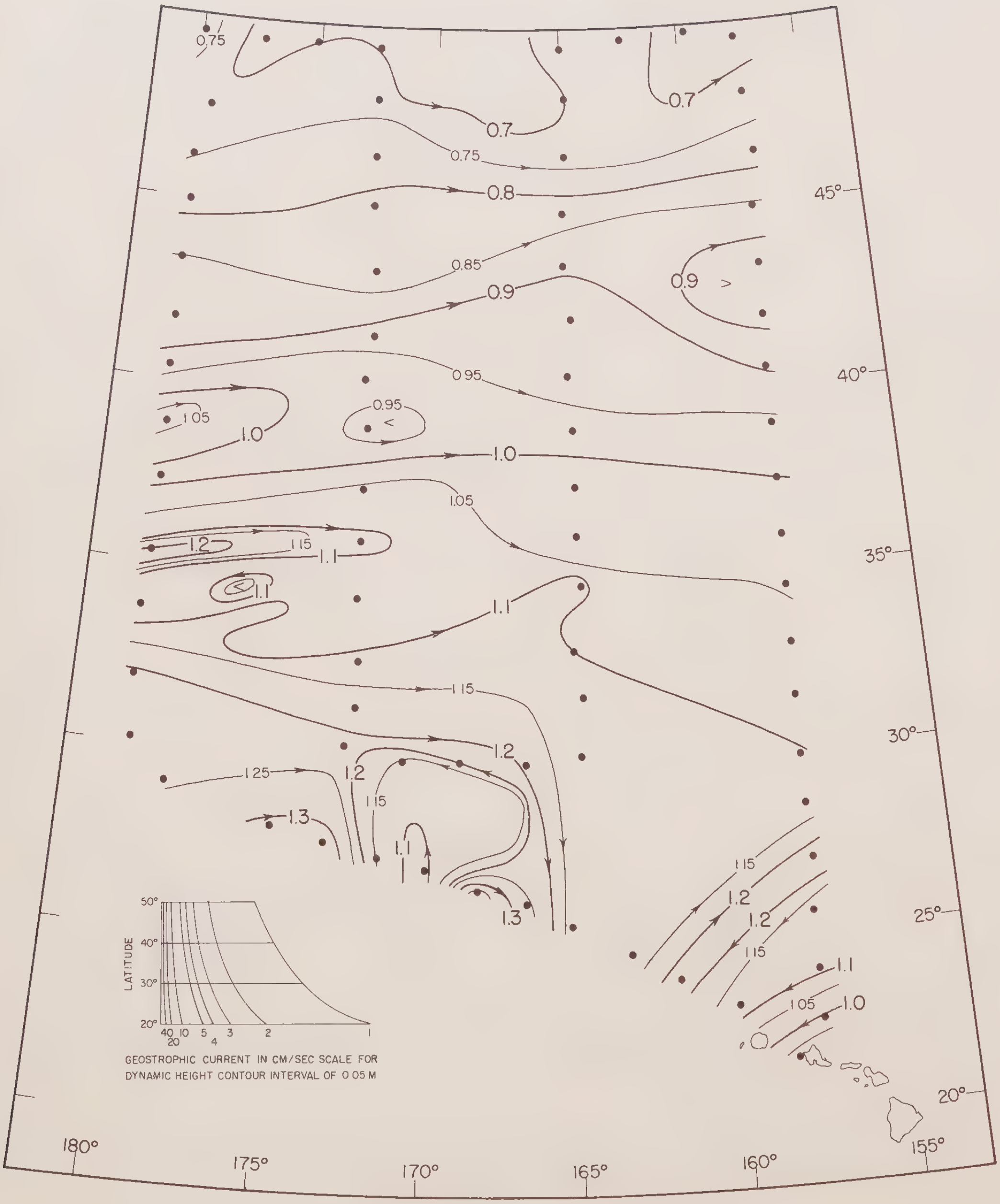

0.75
0.7
0.7
0.75
0.8
45°
0.85
0.9
0.9
40°
0.95
1 05
1.0
0.95
1.0
1.05
1.2
1 15
1.1
35°
1.1
1.1
1 15
30°
1.2
1 25
1.2
1 15
1.3
1.1
1.3
1 15
1.2
1.2
25°
1 15
1.1
1 05
1.0
20°
180°
175°
170°
165°
160°
155°
50°
40°
30°
20°
LATITUDE
40 10 5 3 2 1
20 4
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR
DYNAMIC HEIGHT CONTOUR INTERVAL OF 0 05 M

Figure 116.--Anomaly of the geopotential topography of the 200-db. surface in dynamic meters relative to the 1000-db. surface; *Hugh M. Smith* cruise 30 (NORPAC), July-August 1955. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.05 m.

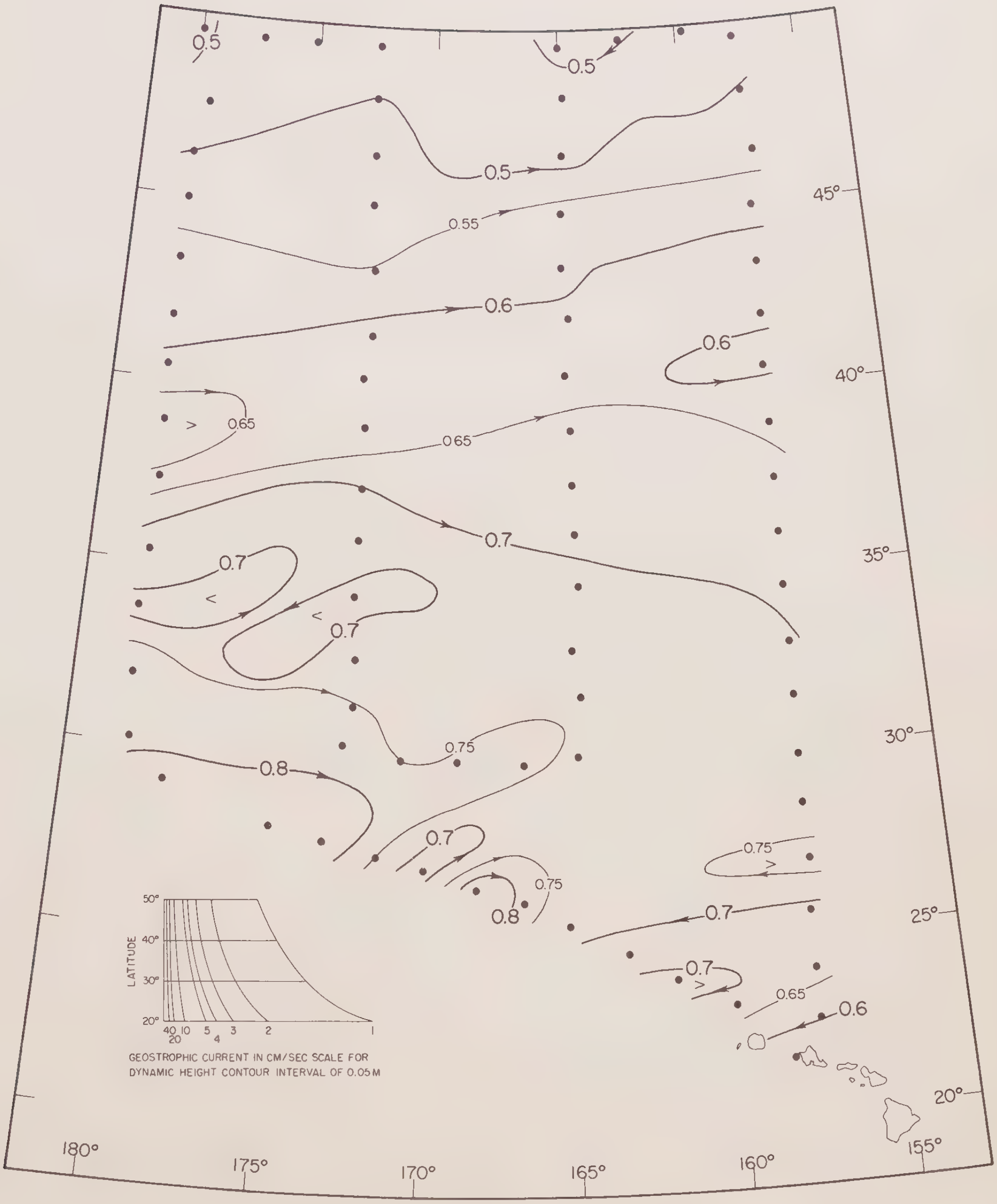

0.5
0.5
0.5
0.55
0.6
0.6
0.65
0.65
0.7
0.7
0.7
0.75
0.8
0.7
0.75
0.8
0.75
0.7
0.7
0.65
0.6
45°
40°
35°
30°
25°
20°
180°
175°
170°
165°
160°
155°
50°
40°
30°
20°
LATITUDE
40 10 5 3 2 1
20 4
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR DYNAMIC HEIGHT CONTOUR INTERVAL OF 0.05 M

Figure 117.--Anomaly of the geopotential topography of the 400-db. surface in dynamic meters relative to the 1000-db. surface; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.05 m.

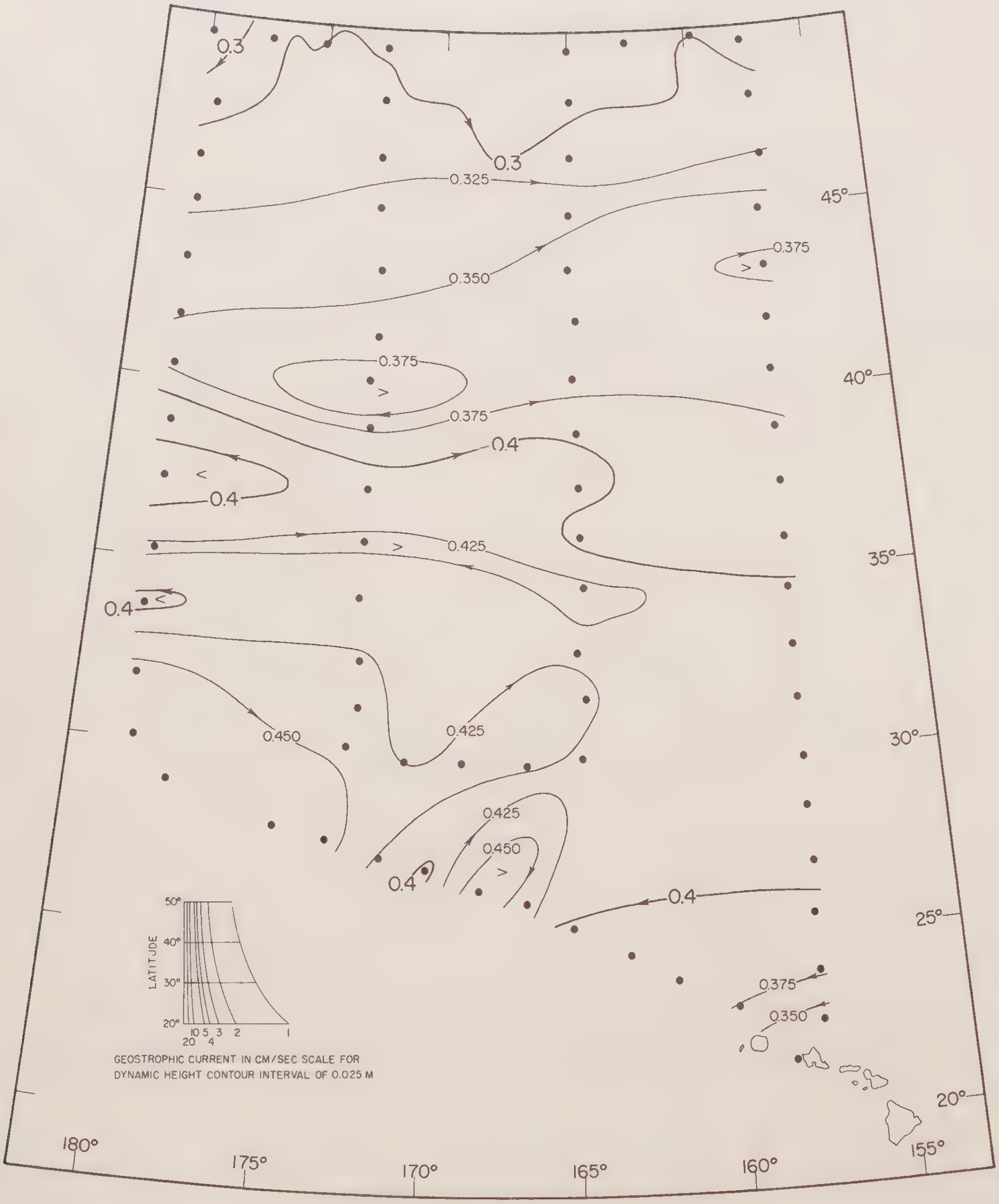

0.3
0.3
0.325
0.350
0.375
45°
0.375
40°
0.375
0.4
0.4
0.425
35°
0.4
0.450
0.425
30°
0.425
0.450
0.4
0.4
25°
0.375
0.350
20°
50°
40°
30°
20°
LATITUDE
10 5 3 2 1
20 4
GEOSTROPHIC CURRENT IN CM/SEC SCALE FOR
DYNAMIC HEIGHT CONTOUR INTERVAL OF 0.025 M
180°
175°
170°
165°
160°
155°

Figure 118.--Anomaly of the geopotential topography of the 600-db. surface in dynamic meters relative to the 1000-db. surface; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Points indicate computed values. Arrows indicate direction of flow. Contour interval 0.025 m.

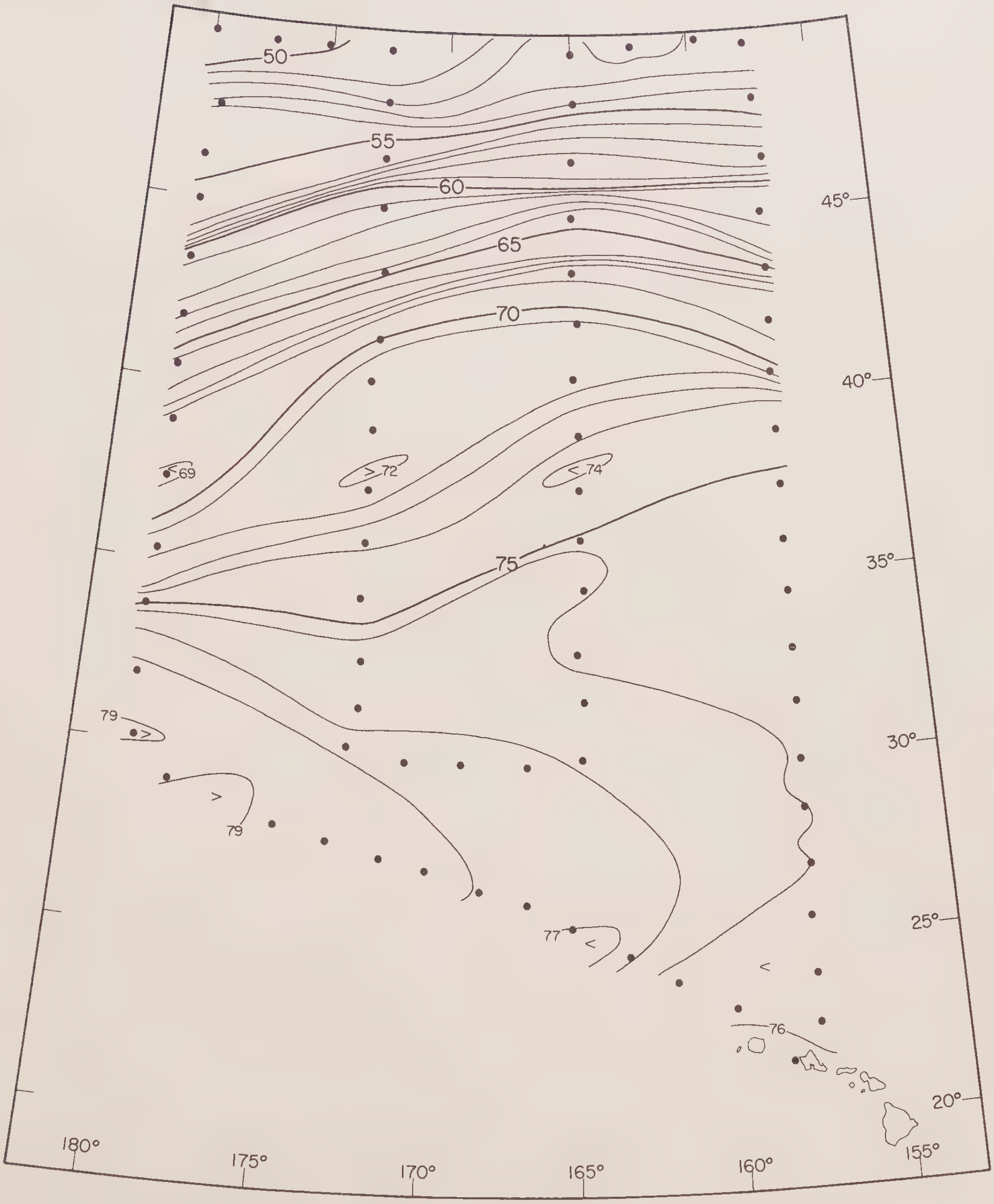

50
55
60
65
70
75
69
72
74
79
79
77
76
45°
40°
35°
30°
25°
20°
180°
175°
170°
165°
160°
155°

Figure 119.--Surface (bucket) temperature in degrees Fahrenheit; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Contour interval 1°F.

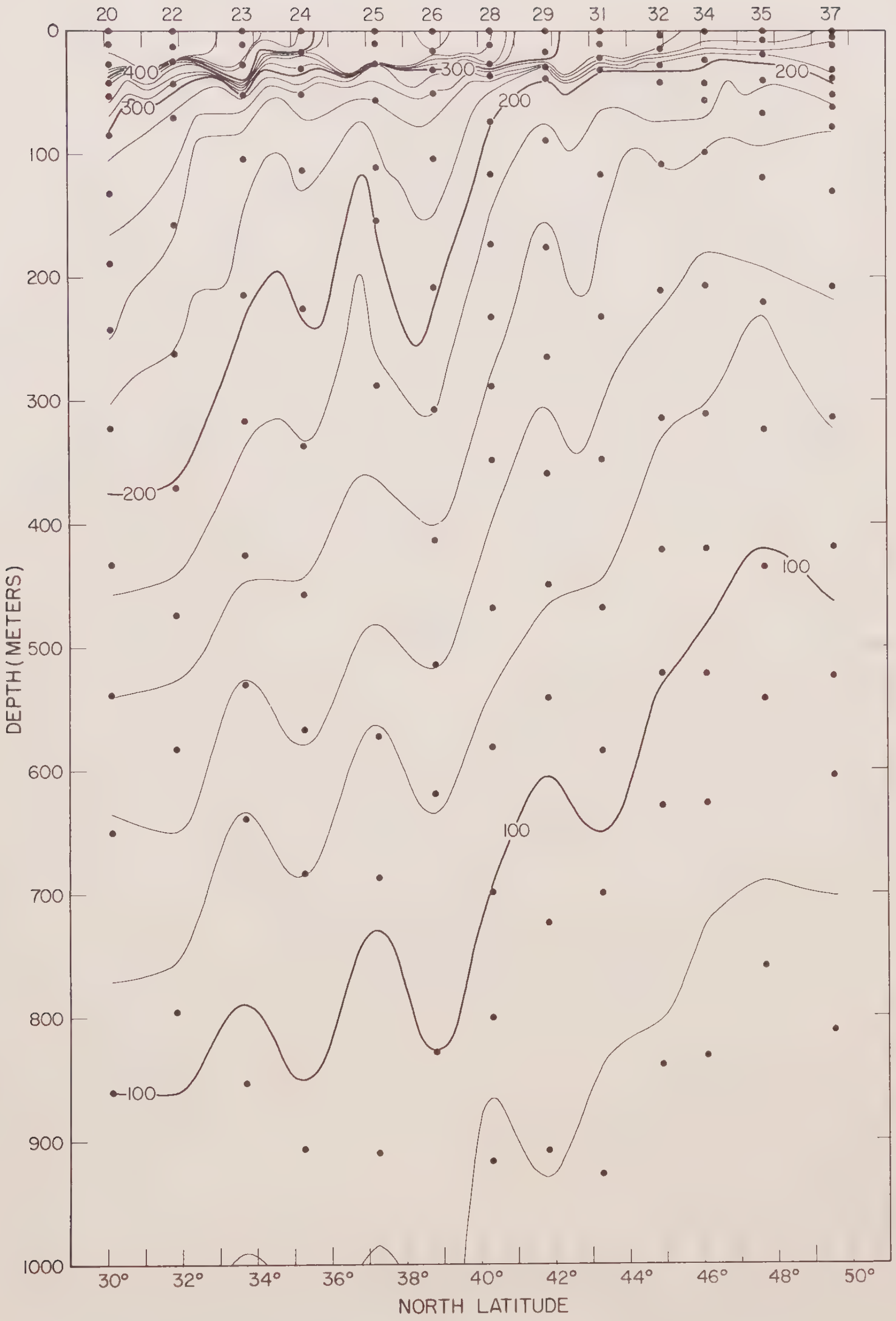


Figure 120.--Vertical section of a thermosteric anomaly in centiliters per ton along the 180th meridian; Hugh M. Smith cruise 30 (NORPAC), stations 20-37, July-August 1955. Contour interval 20 cl./ton. Points indicate observed values.

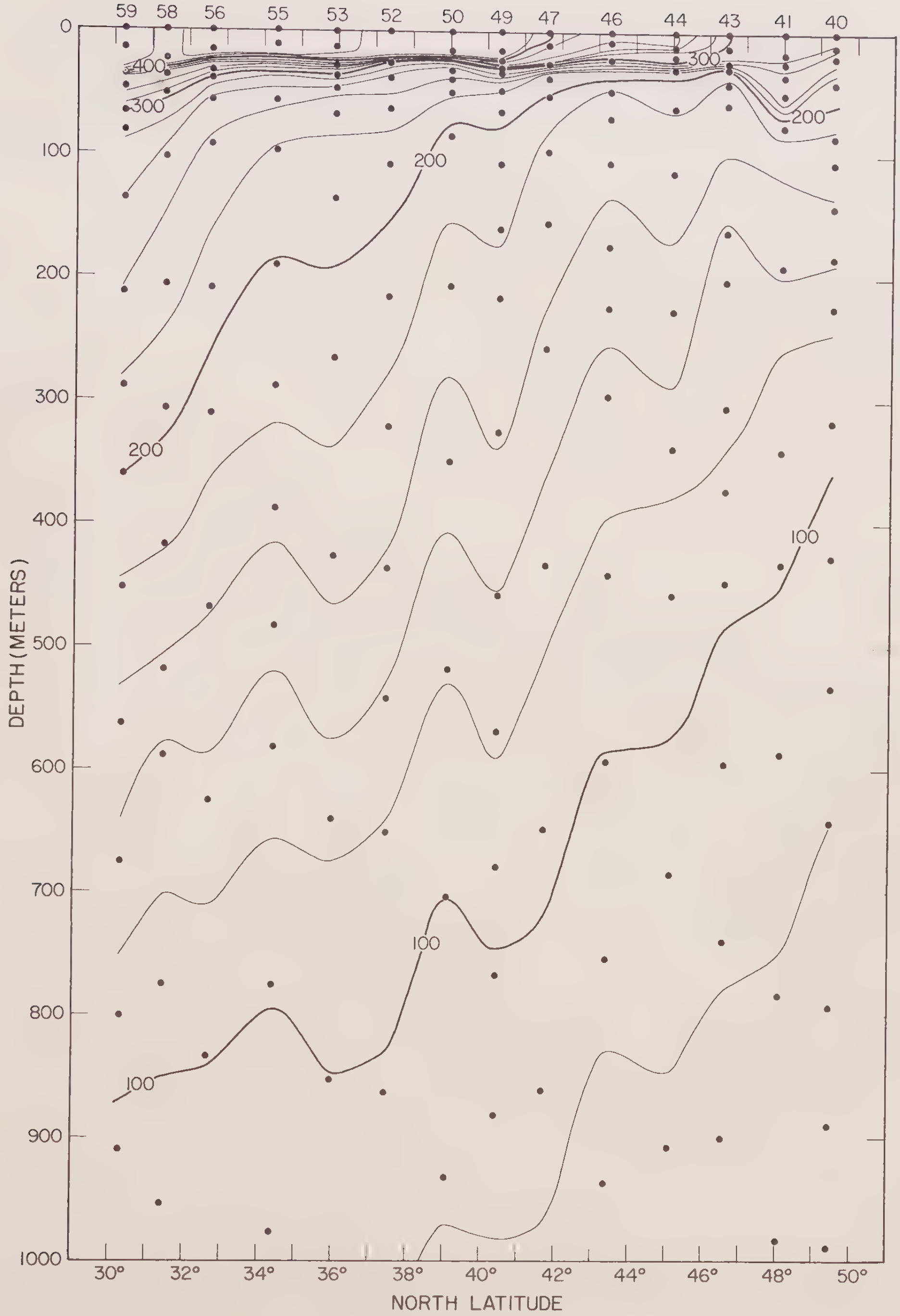


Figure 121.--Vertical section of a thermosteric anomaly in centiliters per ton along 172°30'W. longitude; Hugh M. Smith cruise 30 (NORPAC), stations 40-59, July-August 1955. Contour interval 20 cl./ton. Points indicate observed values.

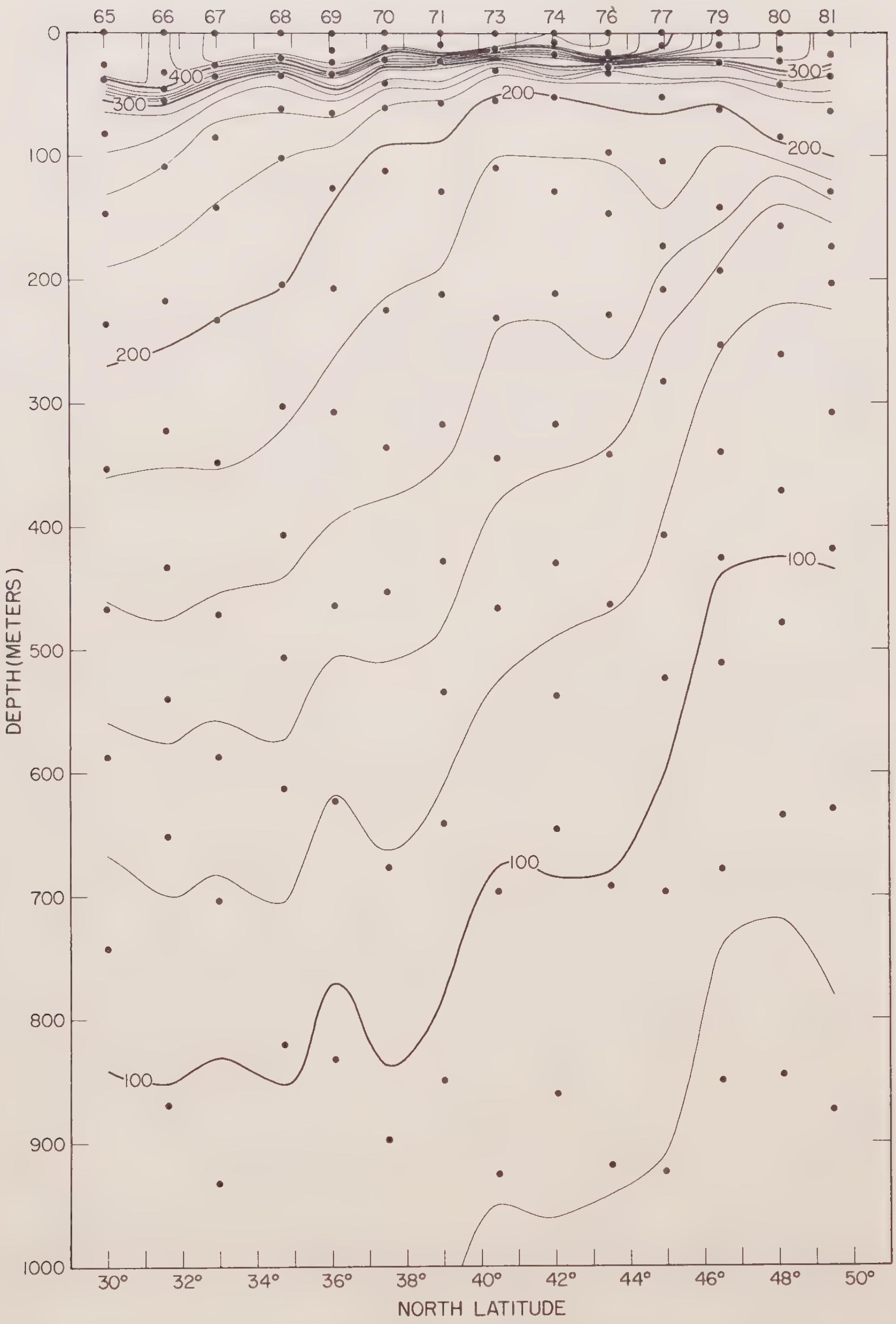


Figure 122.--Vertical section of a thermosteric anomaly in centiliters per ton along 165°W. longitude; Hugh M. Smith cruise 30 (NORPAC), stations 65-81, July-August 1955. Contour interval 20 cl./ton. Points indicate observed values.

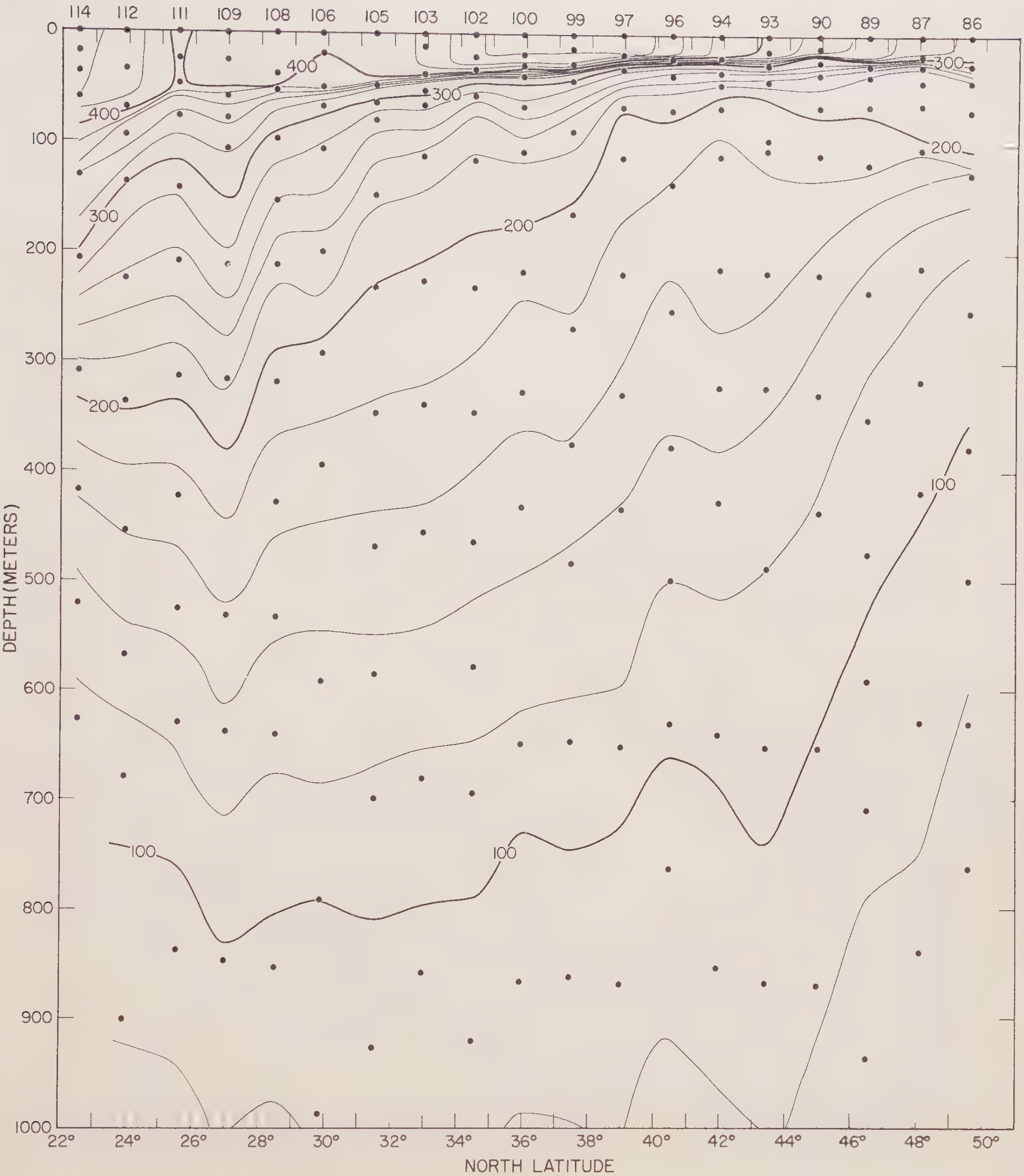


Figure 123.--Vertical section of a thermosteric anomaly in centiliters per ton along 157°30'W. longitude; Hugh M. Smith cruise 30 (NORPAC), stations 86-114, July-August 1955. Contour interval 20 cl. /ton. Points indicate observed values.

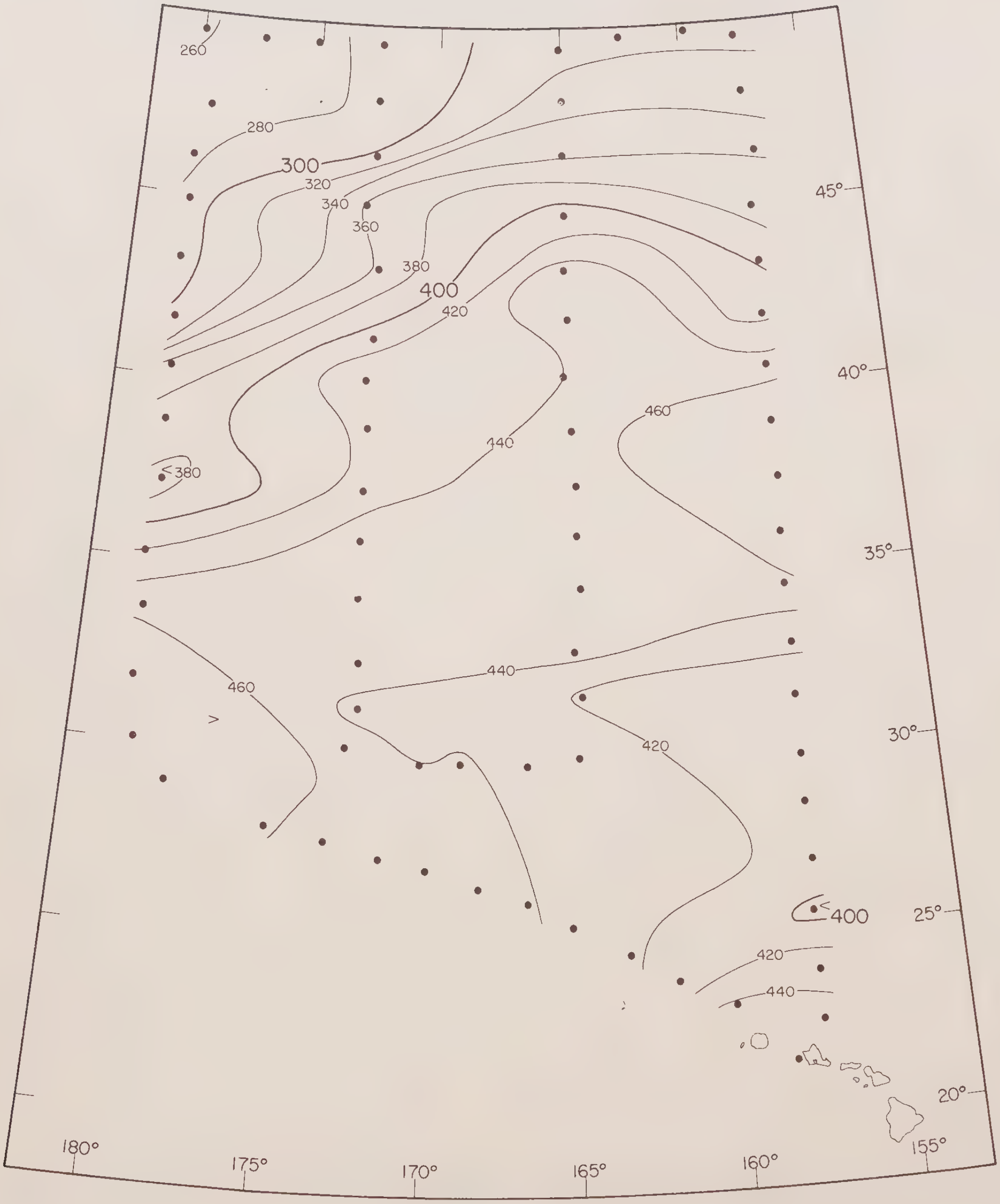
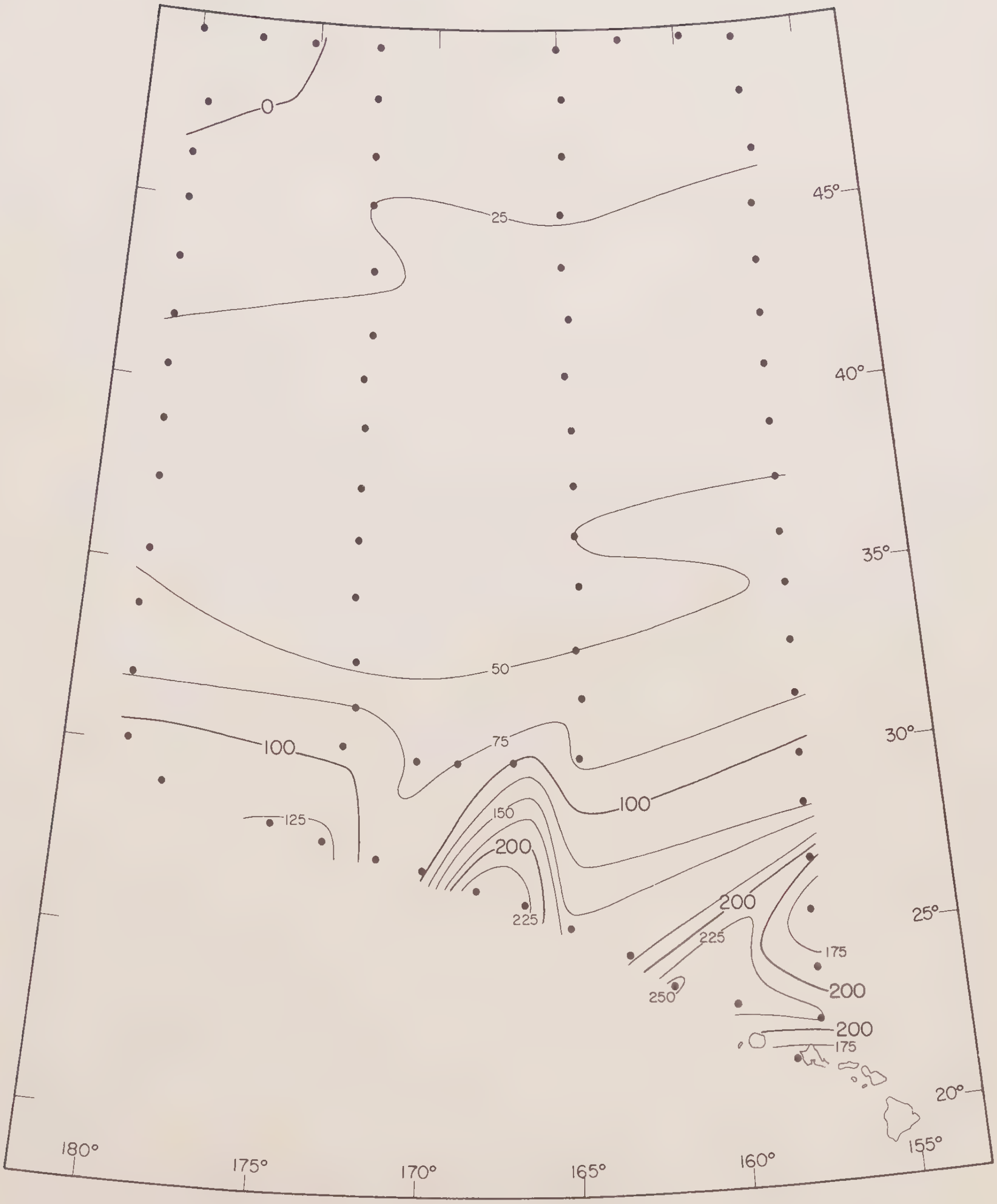

260
280
300
320
340
360
380
400
420
440
460
<380
460
>
440
420
<400
420
440
45°
40°
35°
30°
25°
20°
180°
175°
170°
165°
160°
155°

Figure 124.--Surface thermosteric anomaly in centiliters per ton; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Contour interval 20 cl./ton. Dots indicate station positions.



0
25
50
75
100
100
125
150
200
225
200
225
250
175
200
200
175
45°
40°
35°
30°
25°
20°
180°
175°
170°
165°
160°
155°

Figure 125.--Depth of the 277.7 cl./ton (sigma-t 25.2) thermosteric anomaly surface in meters; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Contour interval 25 meters. Dots indicate station positions.

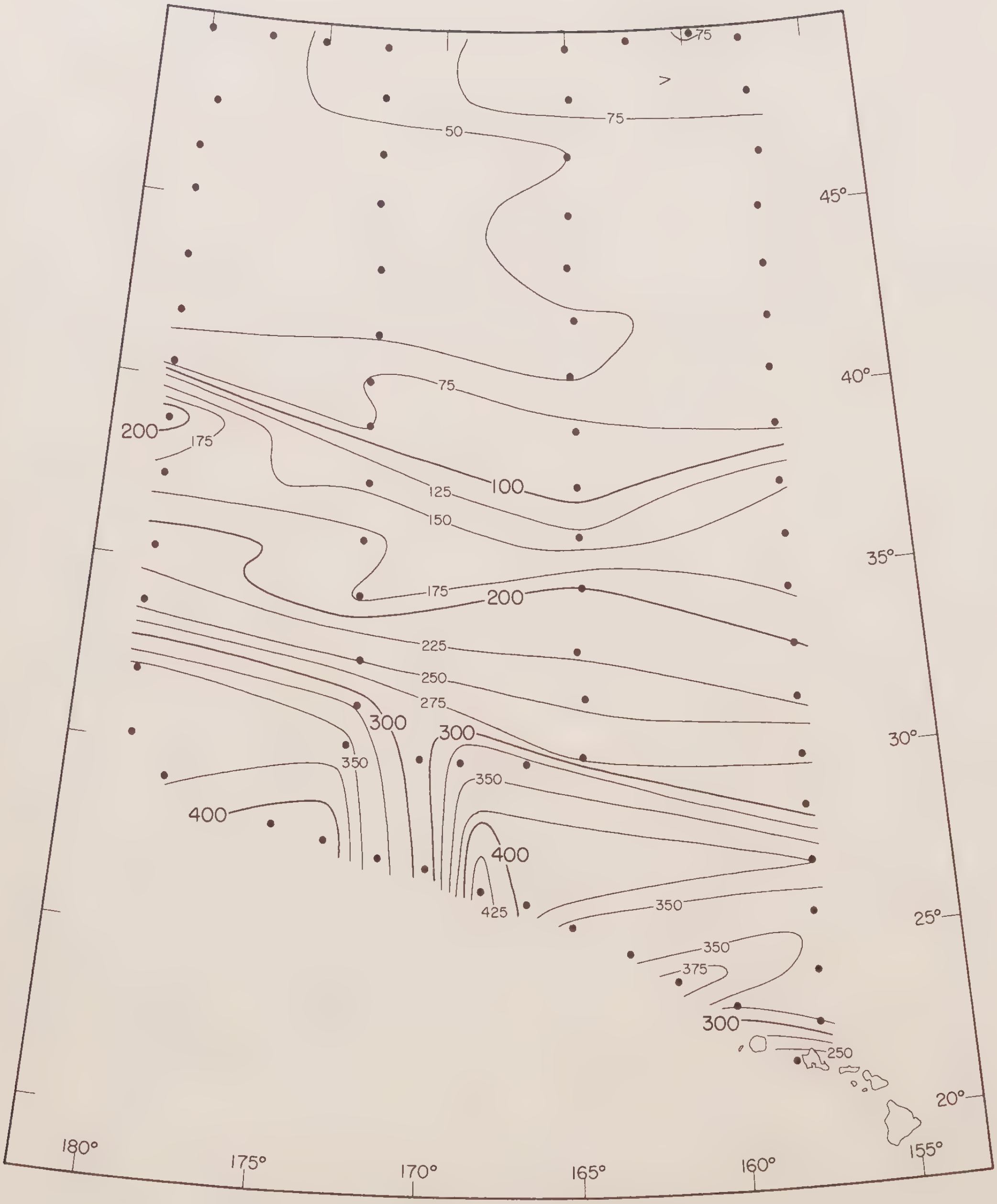

75
50
75
45°
40°
75
200
175
100
125
150
35°
175
200
225
250
275
300
300
30°
350
350
400
400
425
350
25°
350
375
300
250
20°
180°
175°
170°
165°
160°
155°

Figure 126.--Depth of the 201.7 cl./ton (sigma-t 26.0) thermosteric anomaly surface in meters; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Contour interval 25 meters. Dots indicate station positions.

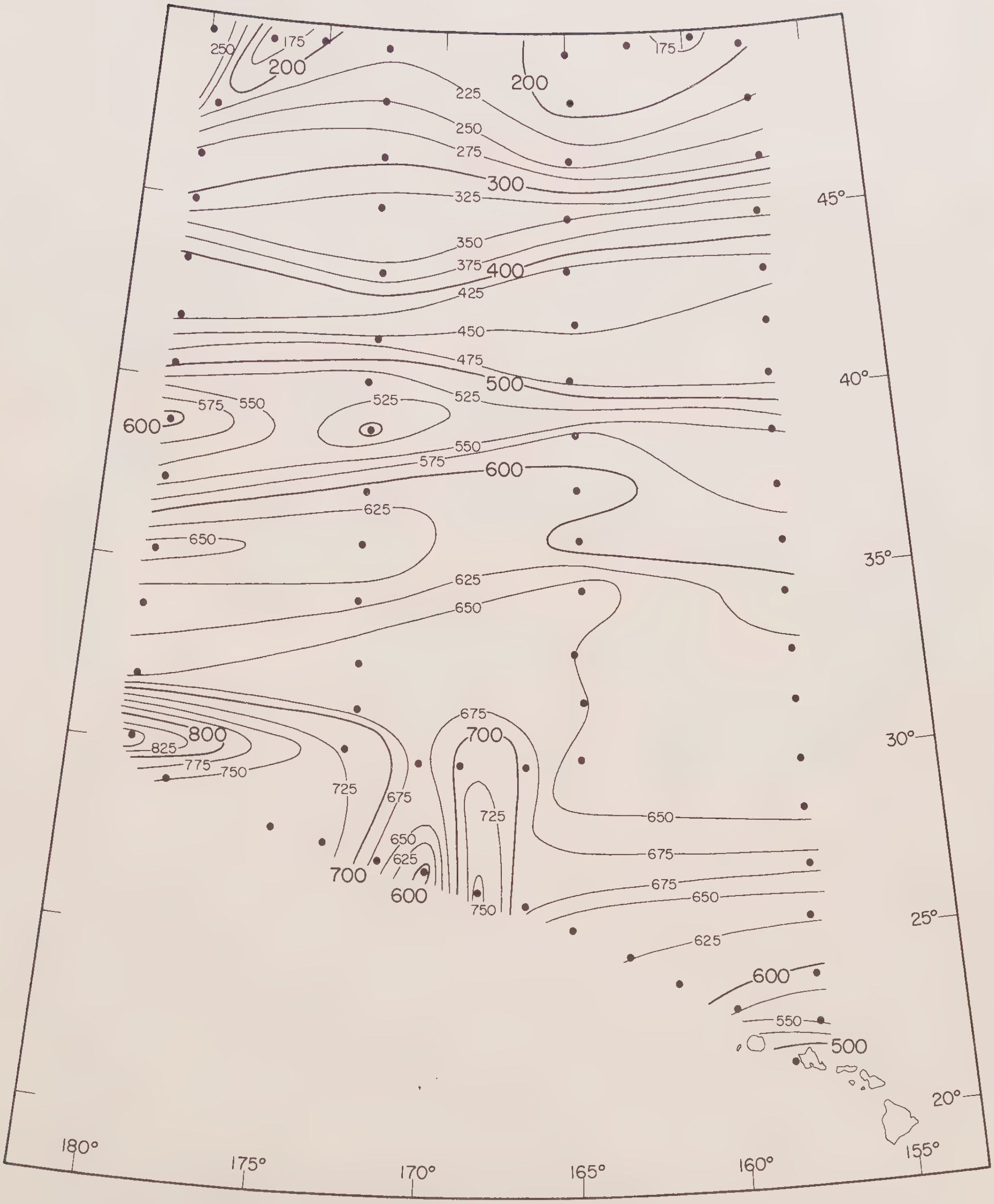

250
175
200
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
525
600
575
550
550
575
600
625
650
625
650
675
700
800
825
775
750
725
675
725
650
625
700
600
750
650
675
675
650
625
600
550
500
45°
40°
35°
30°
25°
20°
180°
175°
170°
165°
160°
155°

Figure 127.--Depth of the 125.5 cl./ton (sigma-t 26.8) thermosteric anomaly surface in meters; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Contour interval 25 meters. Dots indicate station positions.

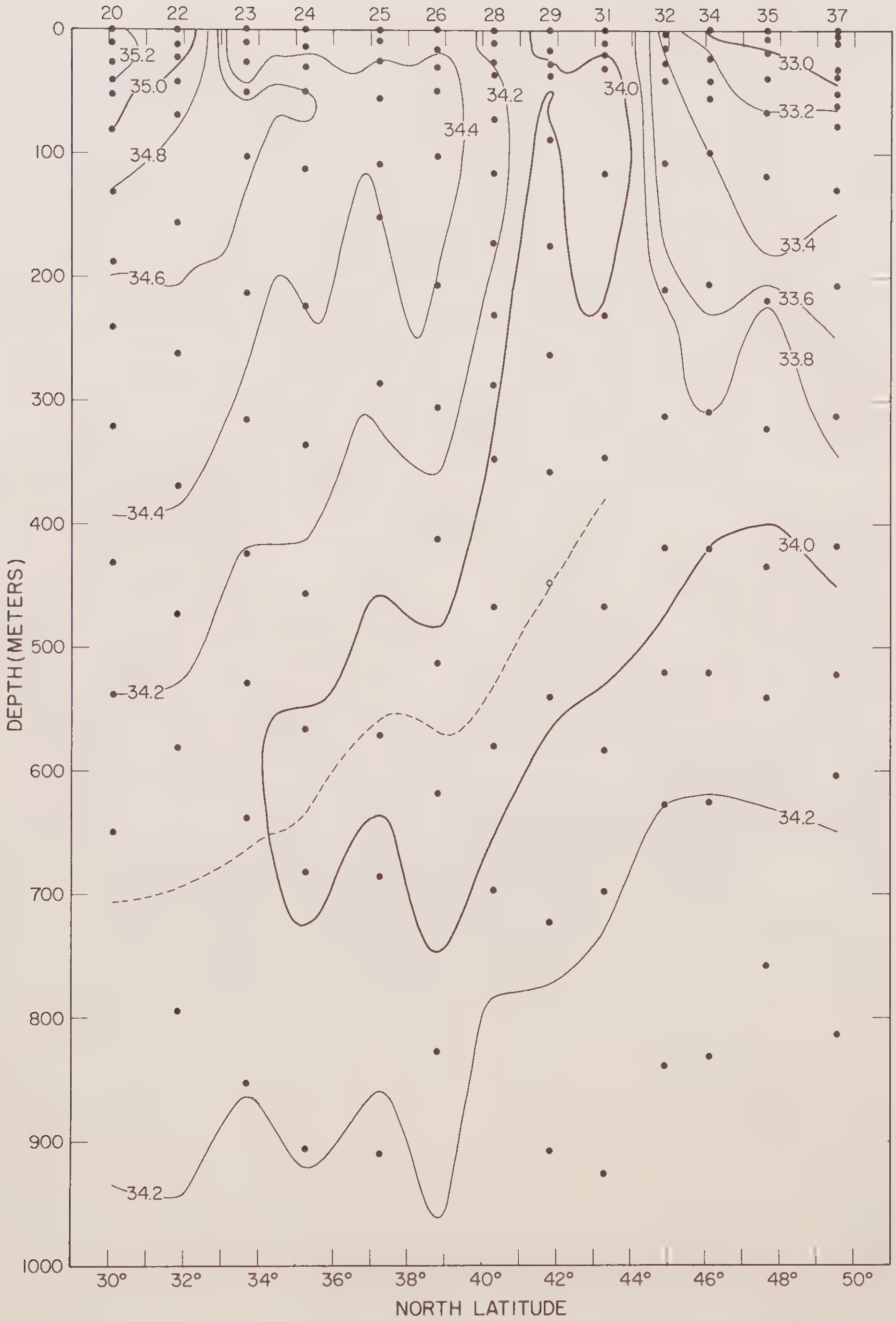


Figure 128.--Vertical section of salinity in parts per thousand along the 180th meridian; Hugh M. Smith cruise 30 (NORPAC), stations 20-37, July-August 1955. Contour interval 0.2 ‰. Points indicate observed values. Dotted line indicates depth of salinity minima.

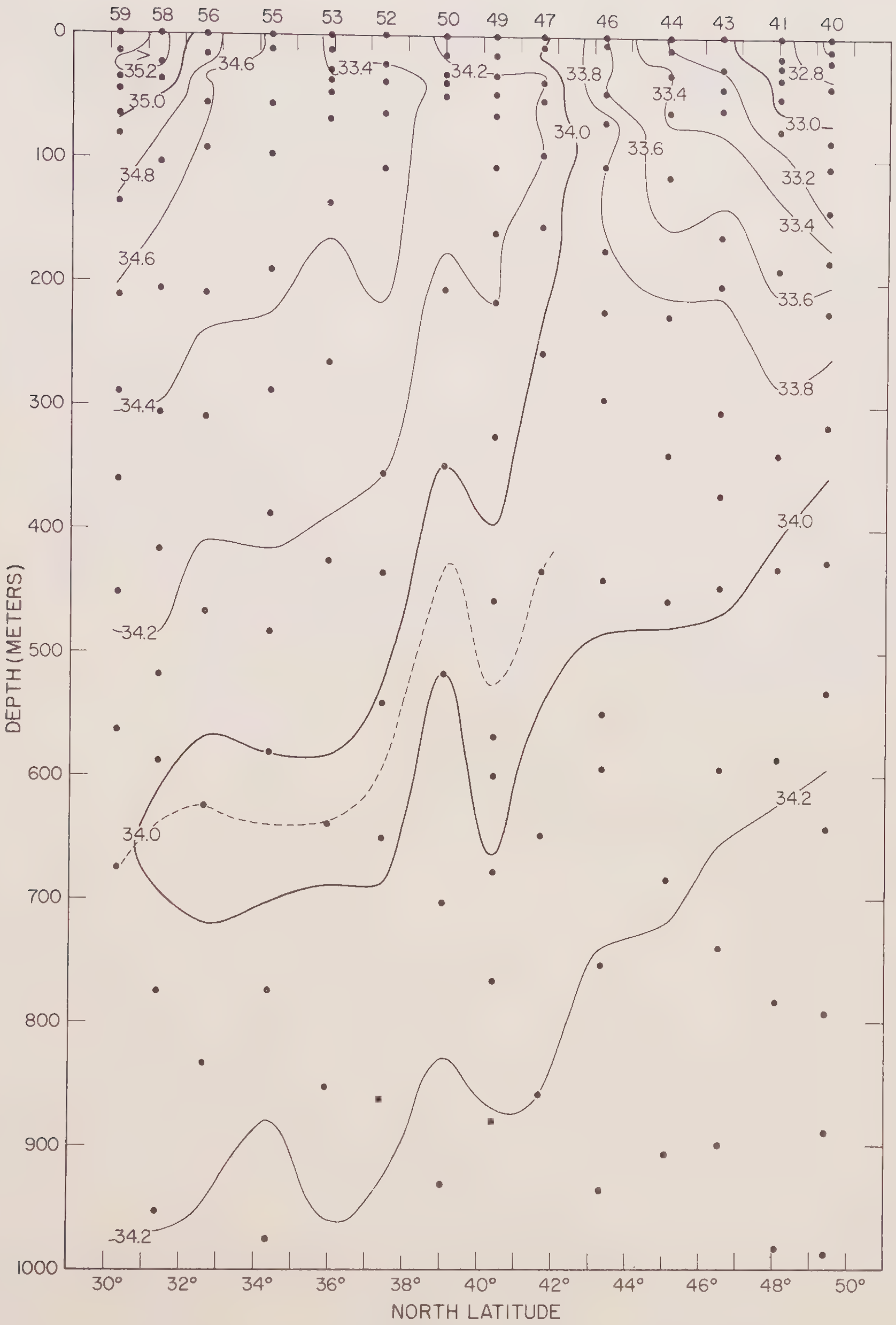


Figure 129.--Vertical section of salinity in parts per thousand along 172°30'W. longitude; *Hugh M. Smith* cruise 30 (NORPAC), stations 40-59, July-August 1955. Contour interval 0.2 ‰. Points indicate observed values. Dotted line indicates depth of salinity minima.

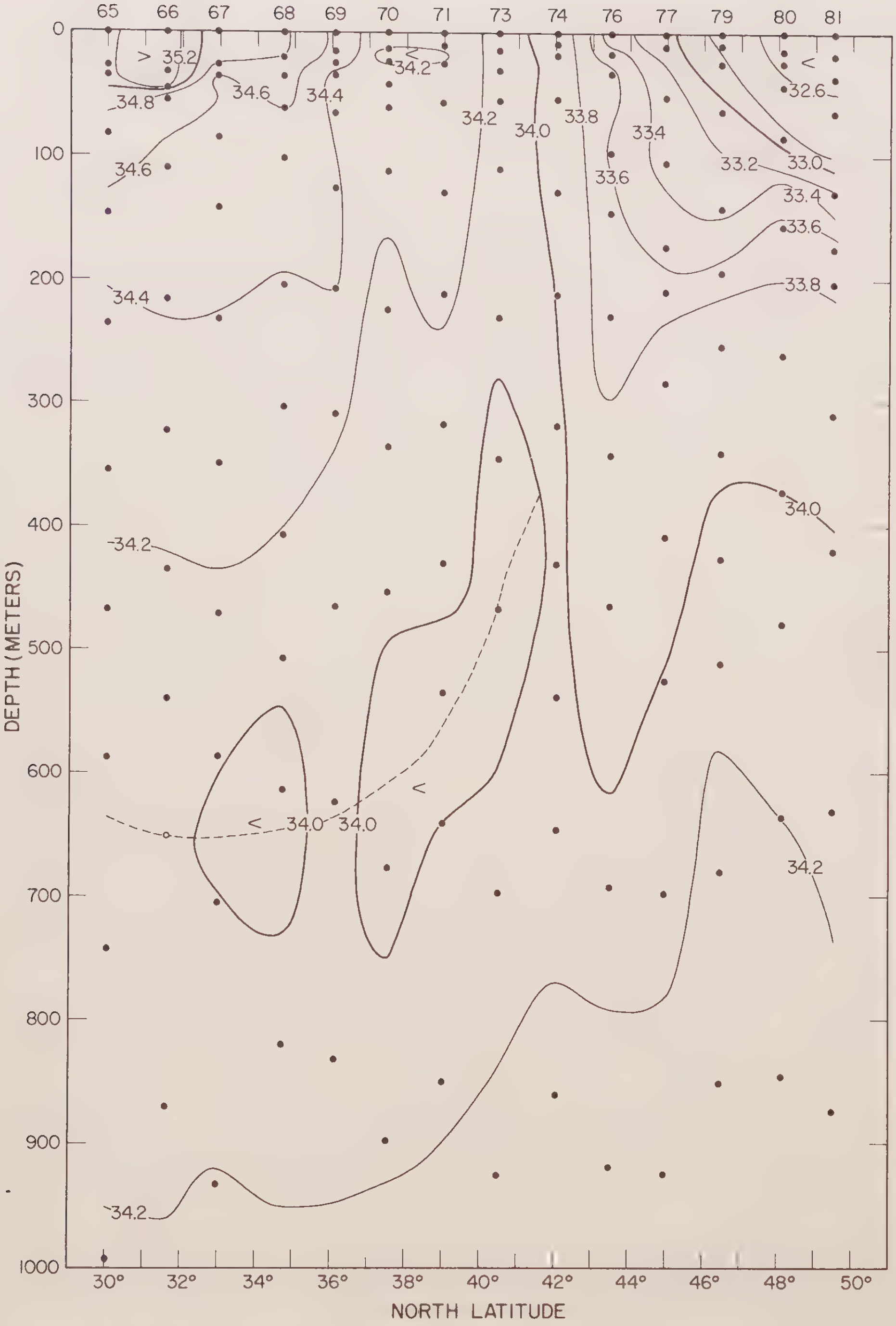


Figure 130.--Vertical section of salinity in parts per thousand along 165°W. longitude; Hugh M. Smith cruise 30 (NORPAC), stations 65-81, July-August 1955. Contour interval 0.2 ‰. Points indicate observed values. Dotted line indicates depth of salinity minima.

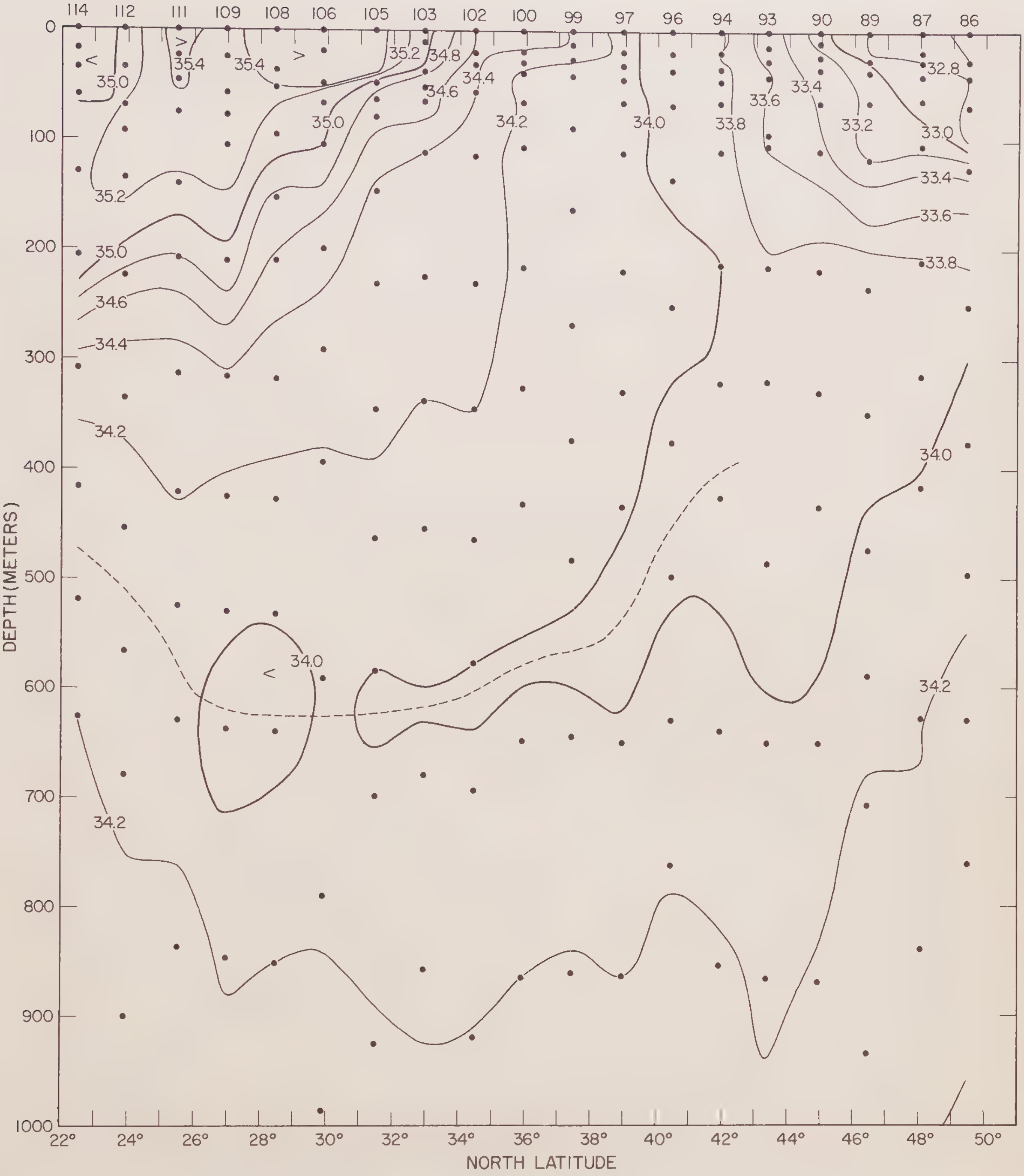


Figure 131.--Vertical section of salinity in parts per thousand along 157°30'W. longitude; Hugh M. Smith cruise 30 (NORPAC), stations 86-114, July-August 1955. Contour interval 0.2 ‰. Points indicate observed values. Dotted line indicates depth of salinity minima.

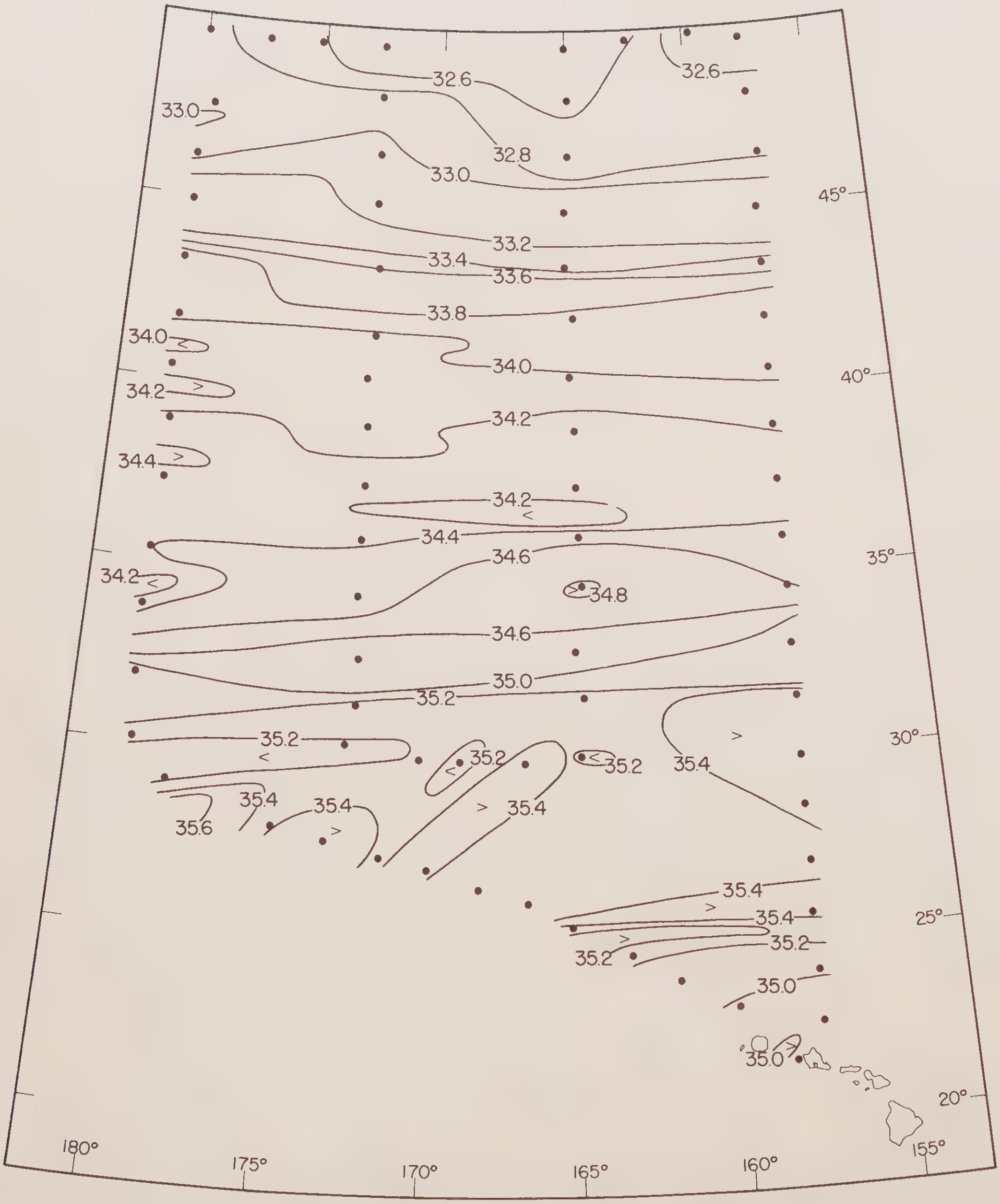

32.6
32.6
33.0
32.8
33.0
33.2
33.4
33.6
33.8
34.0
34.0
34.2
34.2
34.4
34.2
34.4
34.6
34.2
34.8
34.6
35.0
35.2
35.2
35.2
35.2
35.4
35.4
35.4
35.4
35.6
35.4
35.4
35.4
35.2
35.2
35.0
35.0
45°
40°
35°
30°
25°
20°
180°
175°
170°
165°
160°
155°

Figure 132.--Surface salinity in parts per thousand; Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Contour interval 0.2 ‰.

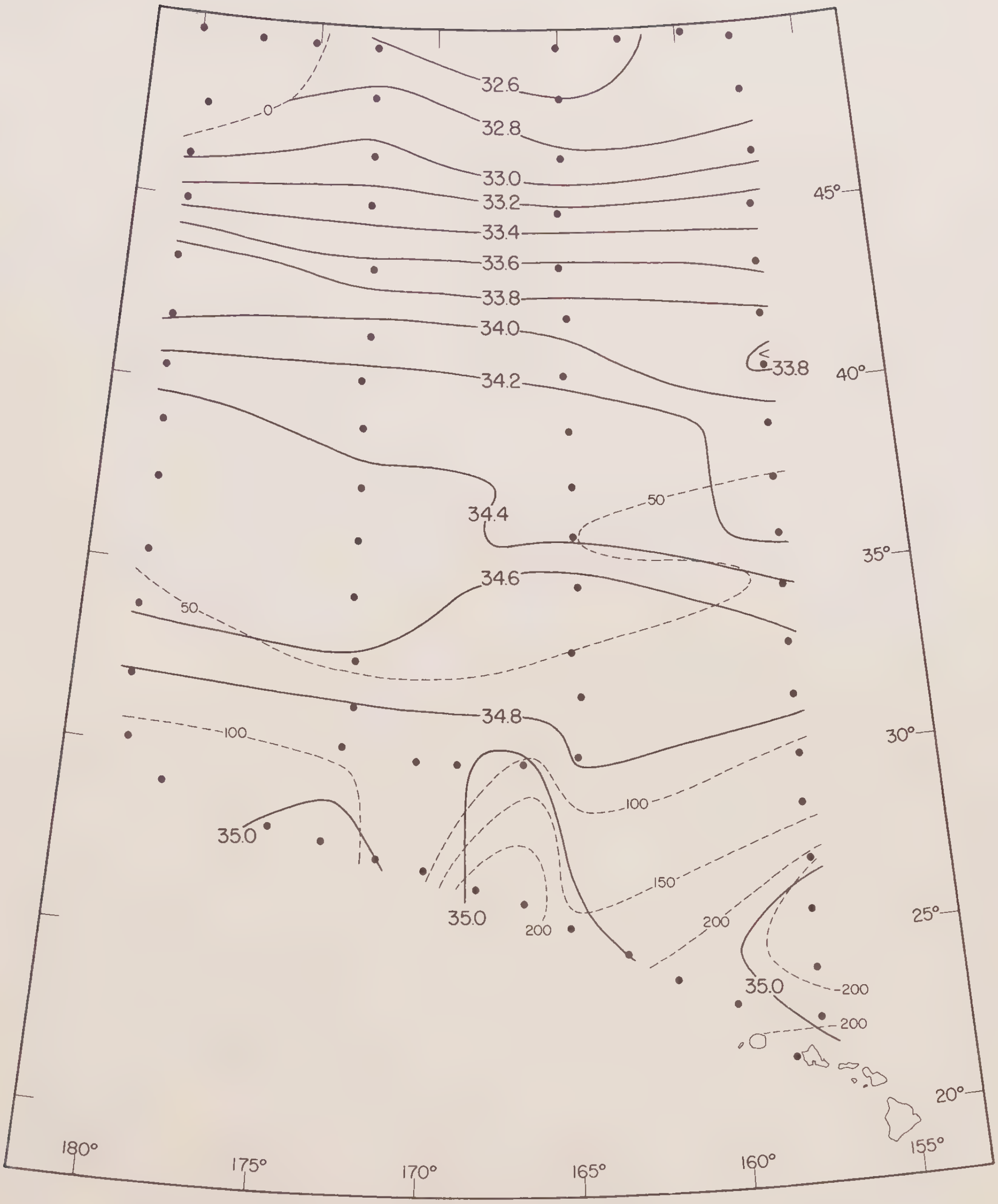

0
32.6
32.8
33.0
33.2
33.4
33.6
33.8
34.0
34.2
33.8
34.4
50
34.6
50
34.8
100
100
35.0
150
35.0
200
200
35.0
200
200
45°
40°
35°
30°
25°
20°
180°
175°
170°
165°
160°
155°

Figure 133.--Salinity in parts per thousand (solid lines) on the 277.7 cl./ton thermosteric anomaly (25.2 sigma-t) surface (depth in meters, dotted lines); Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Contour intervals: salinity 0.2 ‰, depth of the thermosteric anomaly surface 50 m. Dots indicate station positions.

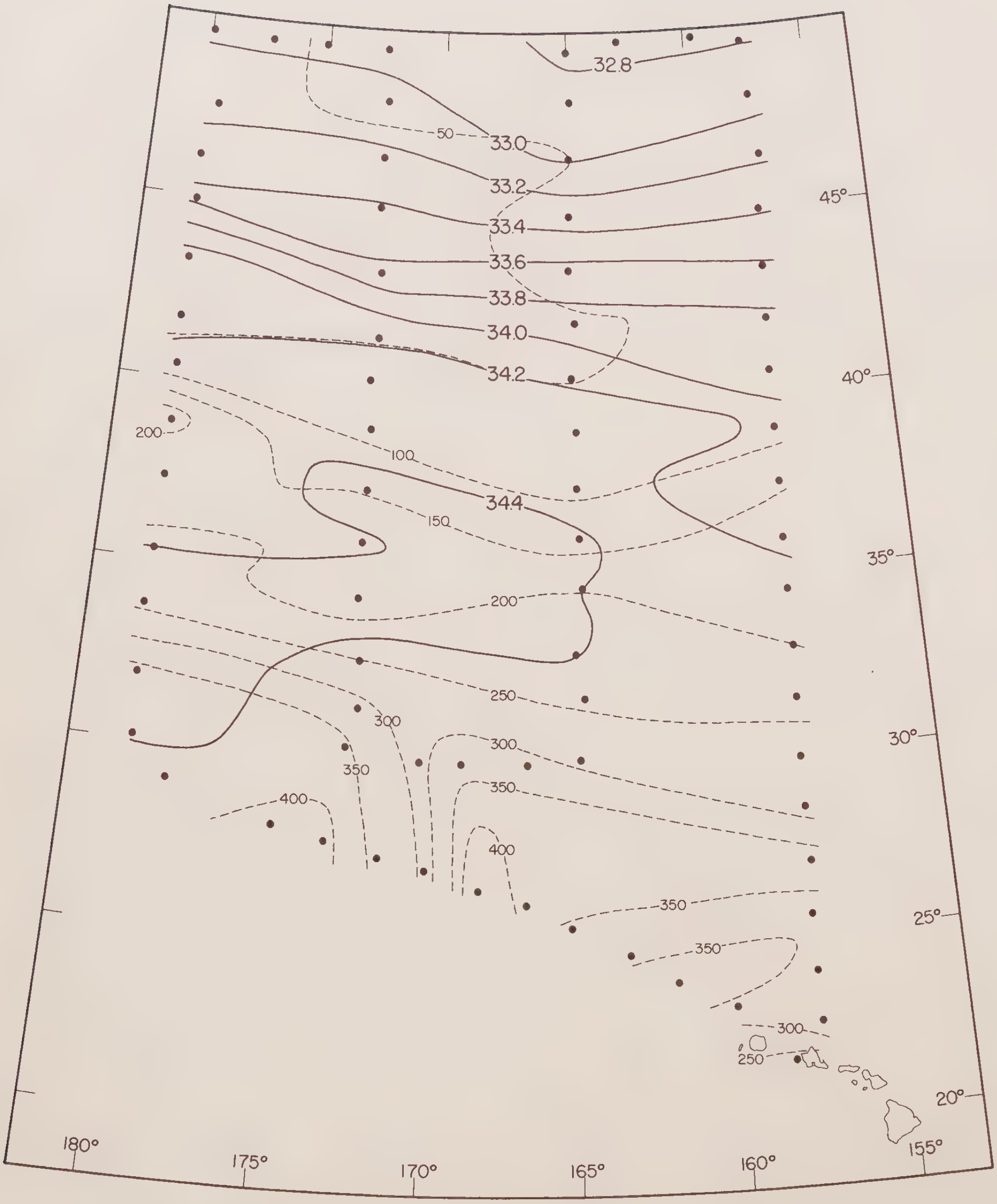

32.8
50
33.0
33.2
33.4
33.6
33.8
34.0
34.2
200
100
34.4
150
200
250
300
300
350
350
400
400
350
350
300
250
45°
40°
35°
30°
25°
20°
180°
175°
170°
165°
160°
155°

Figure 134. --Salinity in parts per thousand (solid lines) on the 201.7 cl./ton thermosteric anomaly (26.0 sigma-t) surface (depth in meters, dotted lines); Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Contour intervals: salinity 0.2 ‰, depth of the thermosteric anomaly surface 50 m. Dots indicate station positions.

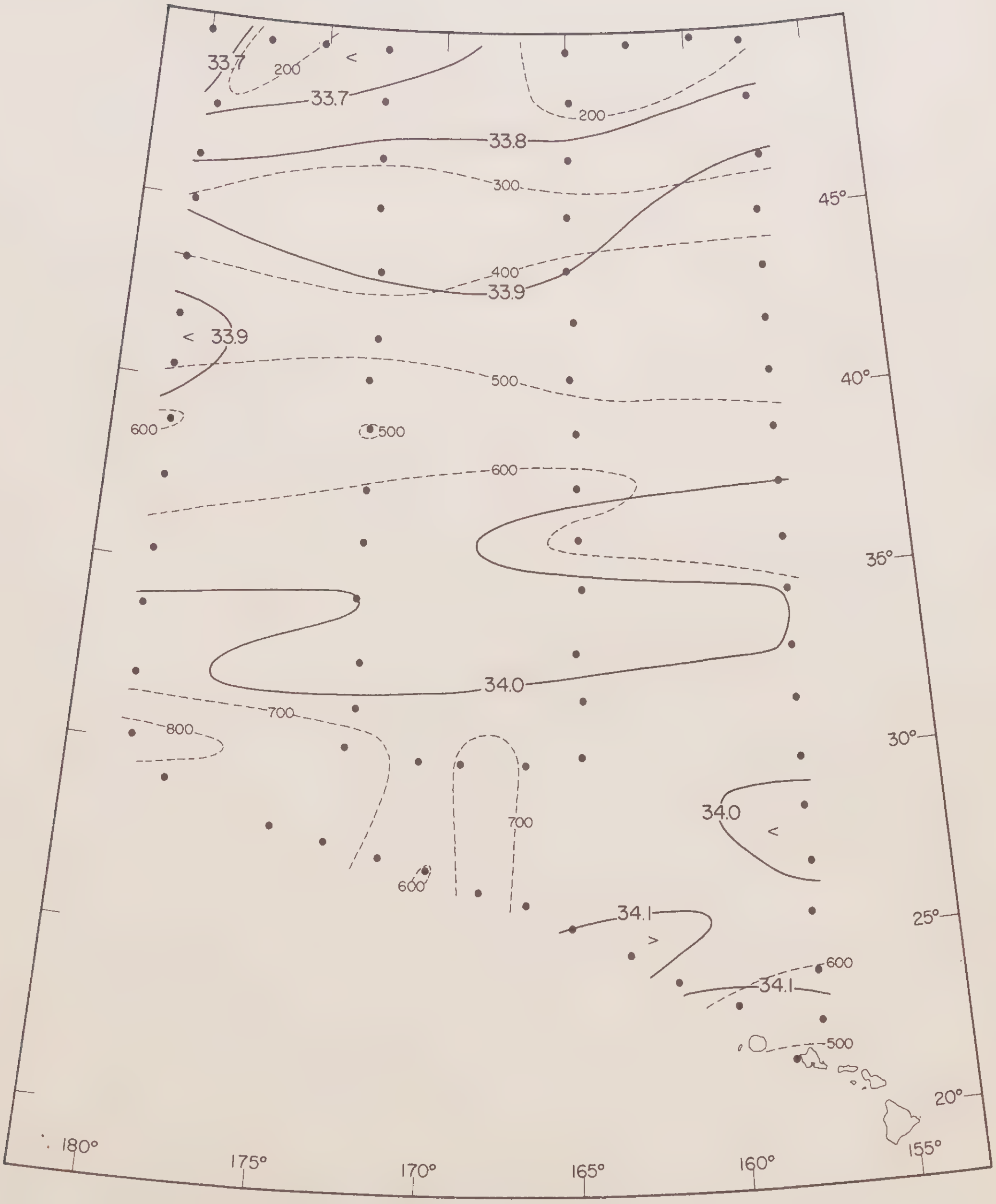

33.7
200
<
33.7
200
33.8
300
45°
400
33.9
< 33.9
500
40°
600
500
600
35°
34.0
700
800
30°
700
34.0
<
600
34.1
>
25°
600
34.1
500
20°
180°
175°
170°
165°
160°
155°

Figure 135.--Salinity in parts per thousand (solid lines) on the 125.5 cl./ton thermosteric anomaly (26.8 sigma-t) surface (depths in meters, dotted lines); Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Contour intervals: salinity 0.1 ‰, depth of the thermosteric anomaly surface 100 m. Dots indicate station positions.

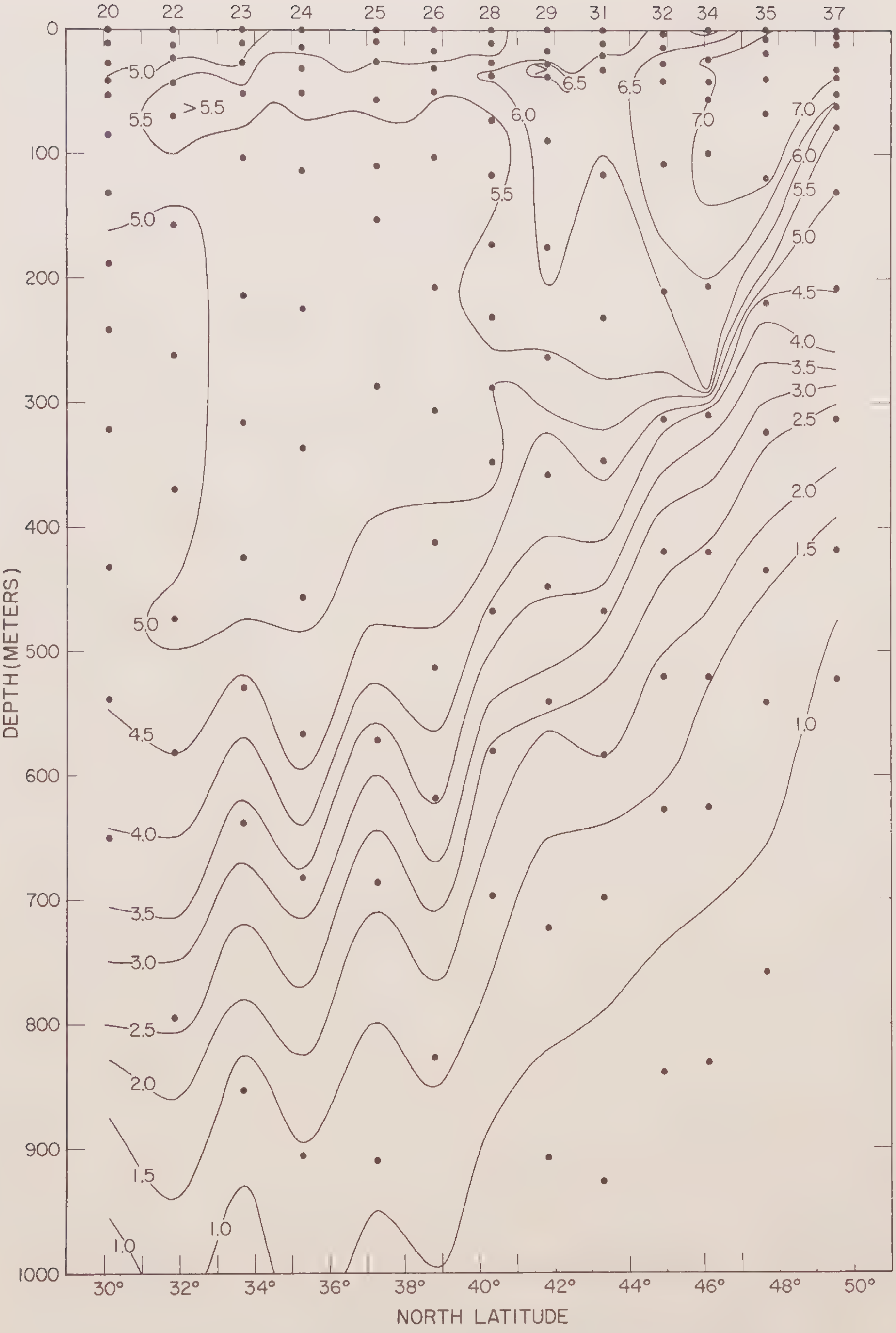


Figure 136.--Vertical section of dissolved oxygen in milliliters per liter along the 180th meridian; Hugh M. Smith cruise 30 (NORPAC), stations 20-37, July-August 1955. Contour interval 0.5 ml. /1. Points indicate observed values.

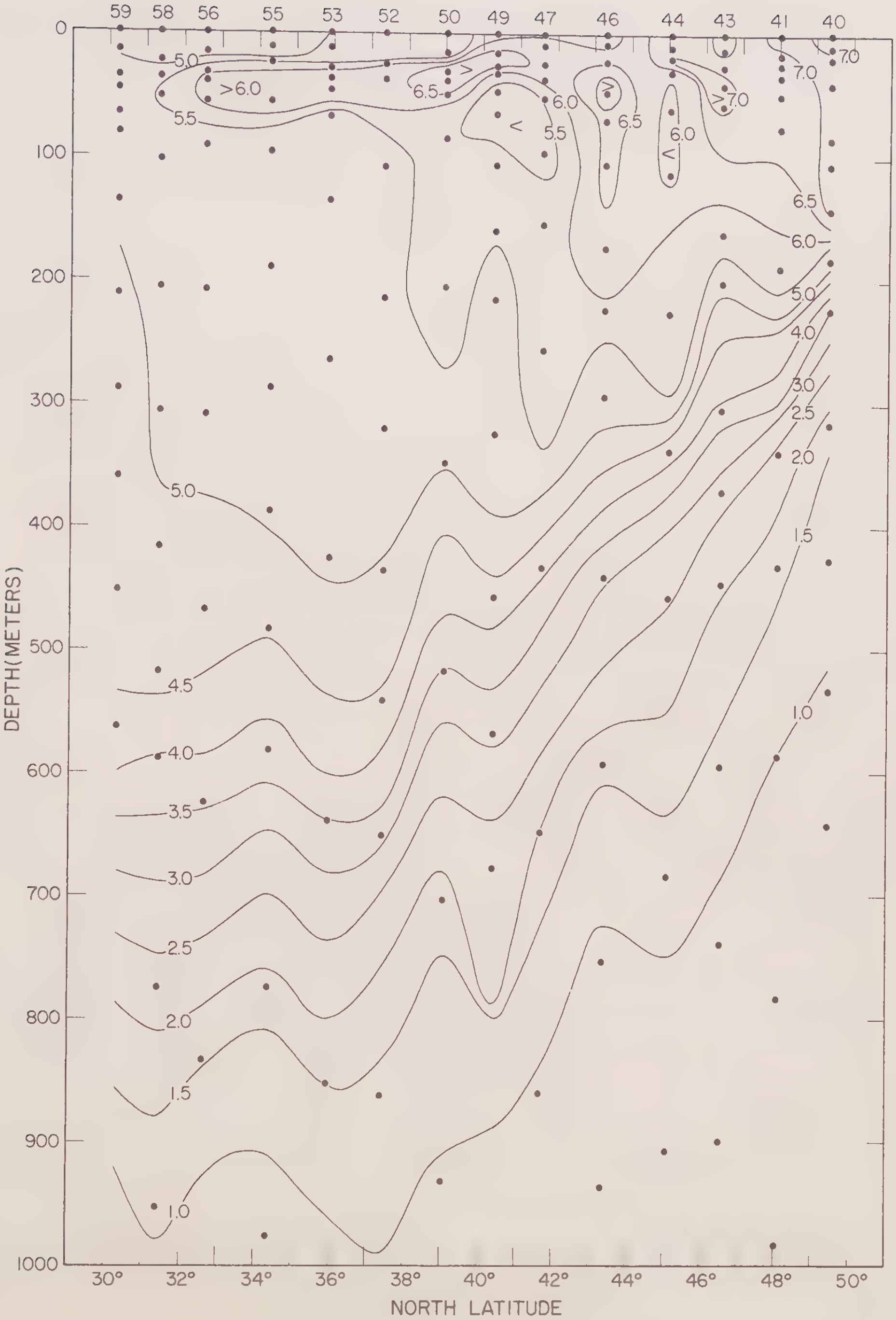


Figure 137.--Vertical section of dissolved oxygen in milliliters per liter along 172°30'W. longitude; Hugh M. Smith cruise 30 (NORPAC), stations 40-59, July-August 1955. Contour interval 0.5 ml. /l. Points indicate observed values.

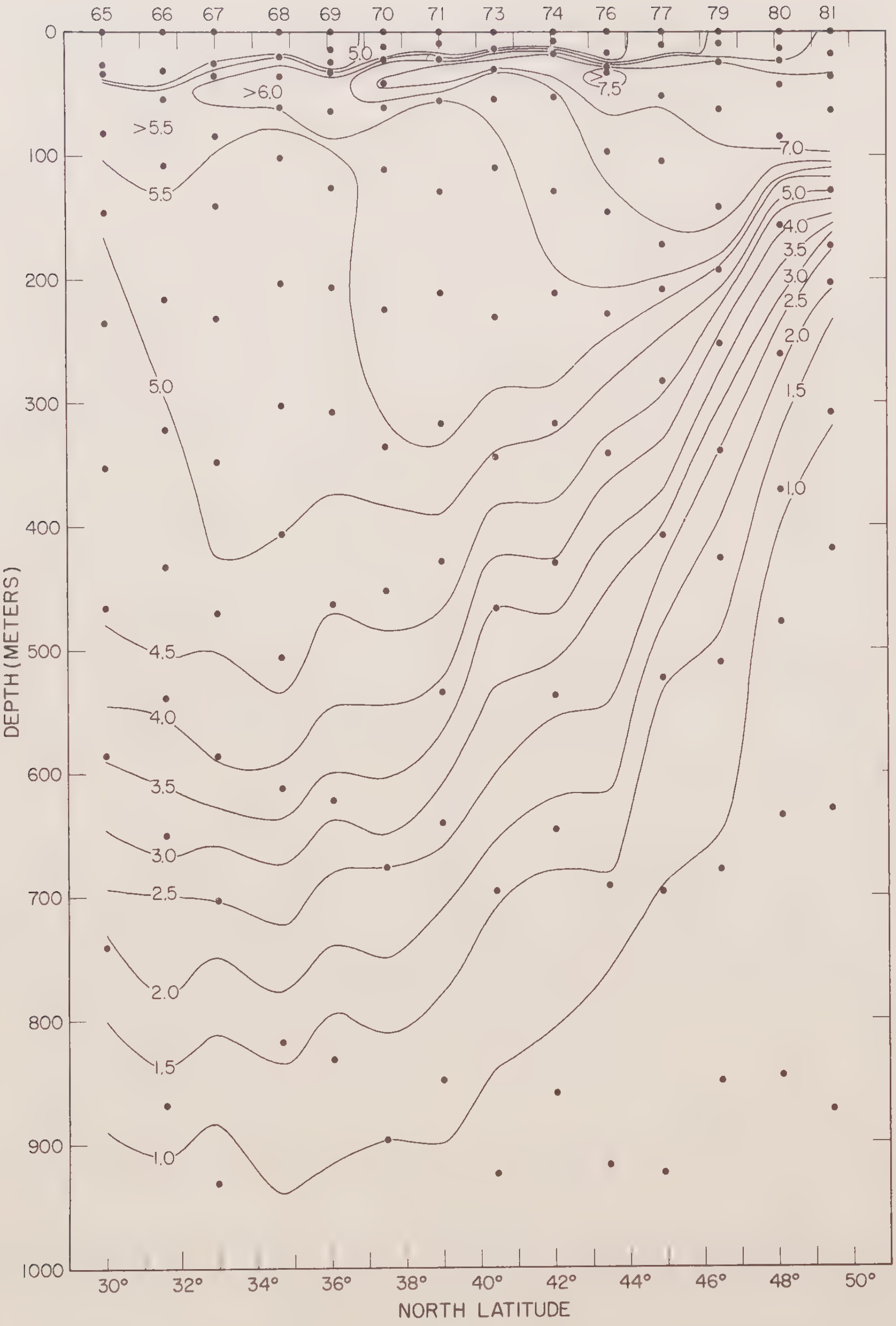


Figure 138.--Vertical section of dissolved oxygen in milliliters per liter along 165°W. longitude; Hugh M. Smith cruise 30 (NORPAC), stations 65-81, July-August 1955. Contour interval 0.5 ml./l. Points indicate observed values.

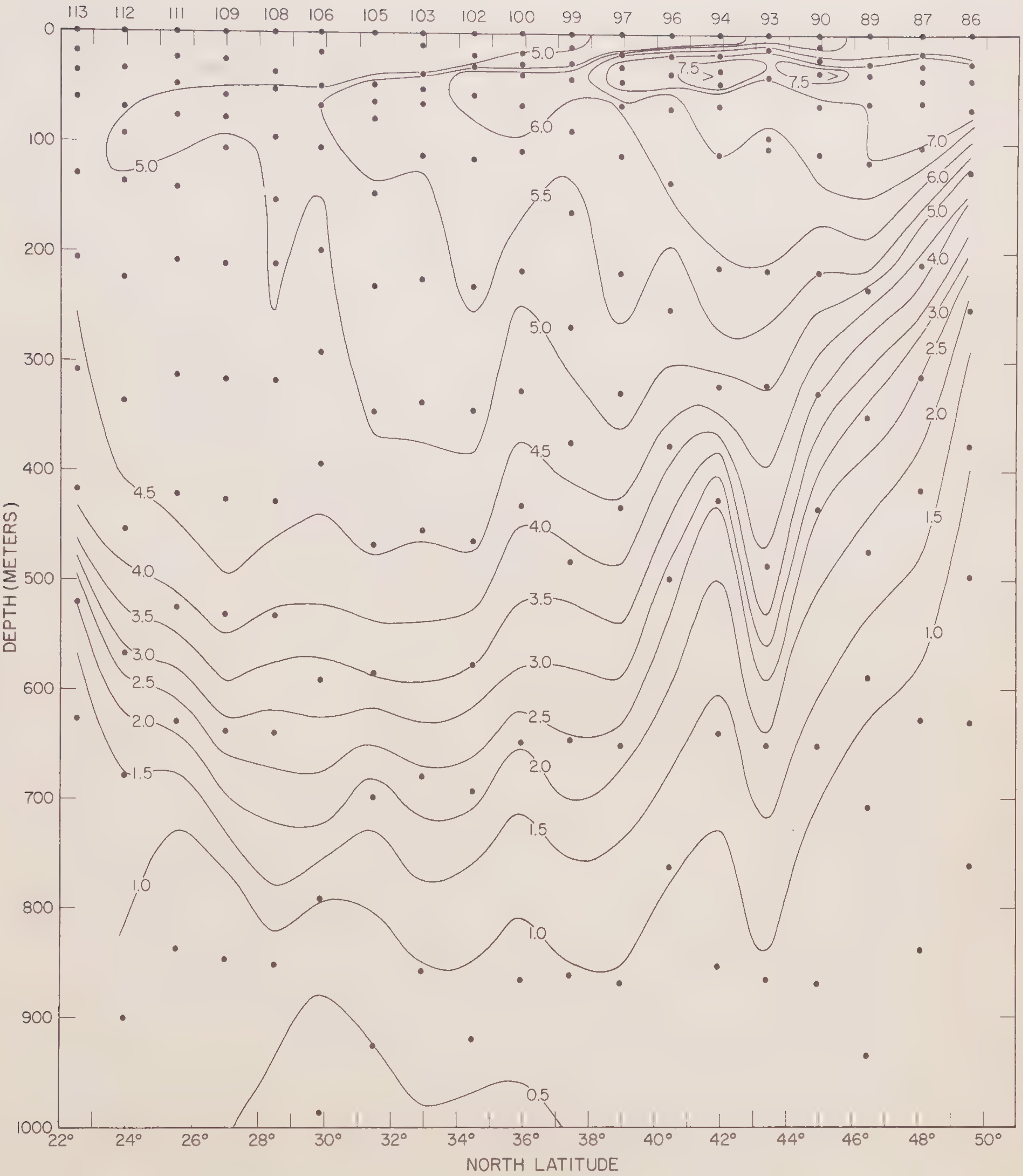


Figure 139.--Vertical section of dissolved oxygen in milliliters per liter along 157°30'W. longitude; Hugh M. Smith cruise 30 (NORPAC), stations 86-114, July-August 1955. Contour interval 0.5 ml./l. Points indicate observed values.

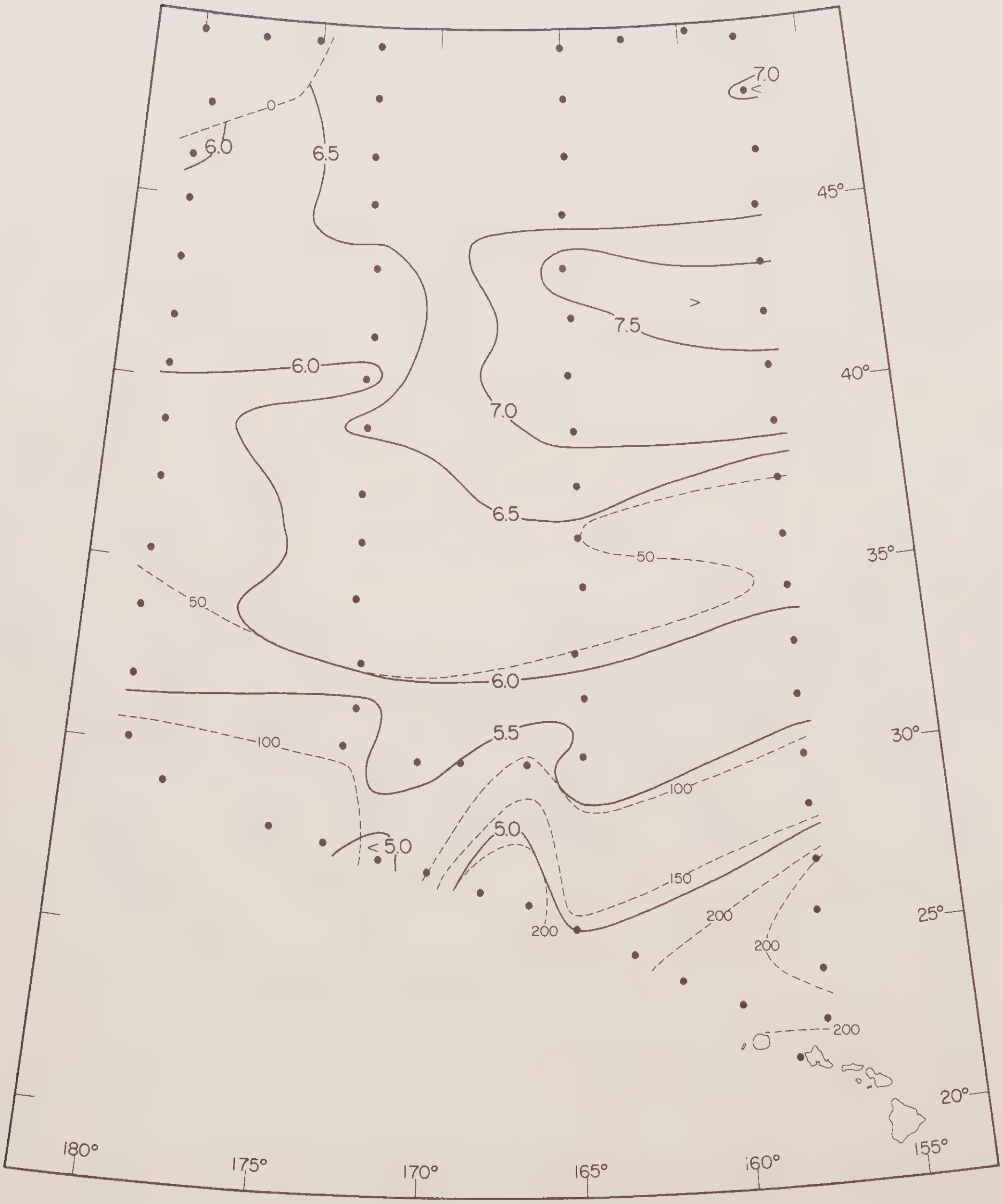

7.0
6.0
6.5
0
45°
7.5
40°
6.0
7.0
6.5
50
35°
50
6.0
5.5
100
30°
100
5.0
< 5.0
150
200
200
200
25°
200
20°
180°
175°
170°
165°
160°
155°

Figure 140.--Dissolved oxygen in milliliters per liter (solid lines) on the 277.7 cl./ton thermosteric anomaly (sigma-t 25.2) surface (depth in meters, dotted lines), Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Contour intervals: dissolved oxygen 0.5 ml./l., depth of thermosteric anomaly surface 50 m.

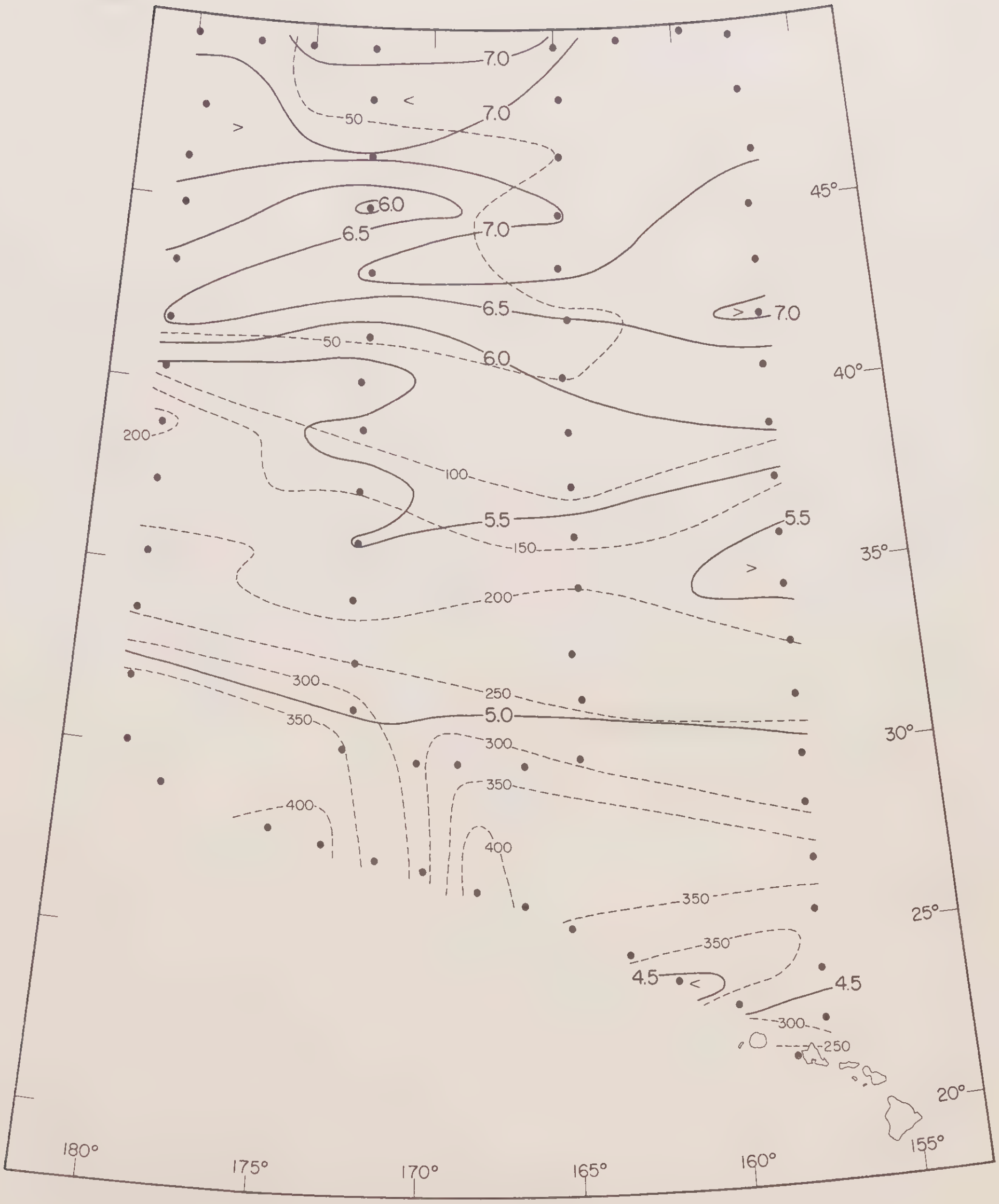

7.0
7.0
50
6.0
6.5
7.0
45°
6.5
7.0
50
6.0
40°
200
100
5.5
5.5
150
35°
200
300
250
5.0
350
300
30°
350
400
400
350
25°
350
4.5
4.5
300
250
20°
180°
175°
170°
165°
160°
155°

Figure 141.--Dissolved oxygen in milliliters per liter (solid lines) on the 201.7 cl./ton thermosteric anomaly (sigma-t 26.0) surface (depth in meters, dotted lines), Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Contour intervals: dissolved oxygen 0.5 ml./l., depth of thermosteric anomaly surface 50 m.

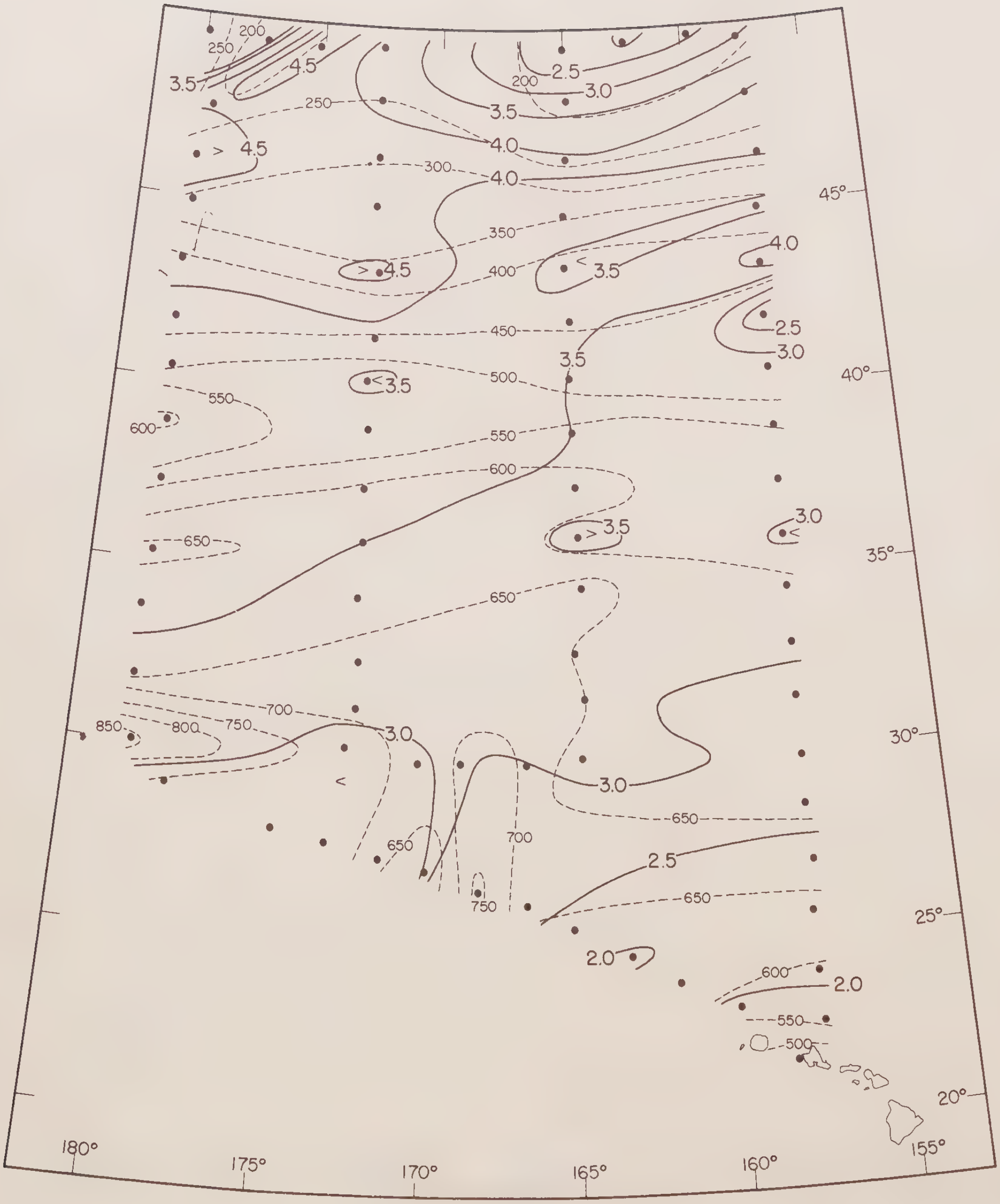

200
250
3.5
4.5
250
> 4.5
300
200
2.5
3.0
3.5
4.0
4.0
45°
350
> 4.5
400
< 3.5
4.0
450
2.5
3.0
3.5
500
40°
< 3.5
550
600
550
600
> 3.5
3.0
<
650
35°
650
700
850
800
750
3.0
<
3.0
30°
650
650
700
2.5
750
650
25°
2.0
600
2.0
550
500
20°
180°
175°
170°
165°
160°
155°

Figure 142.--Dissolved oxygen in milliliters per liter (solid lines) on the 125.5 cl./ton thermosteric anomaly (sigma-t 26.8) surface (depth in meters, dotted lines), Hugh M. Smith cruise 30 (NORPAC), July-August 1955. Contour intervals: dissolved oxygen 0.5 ml./l., depth of thermosteric anomaly surface 50 m.

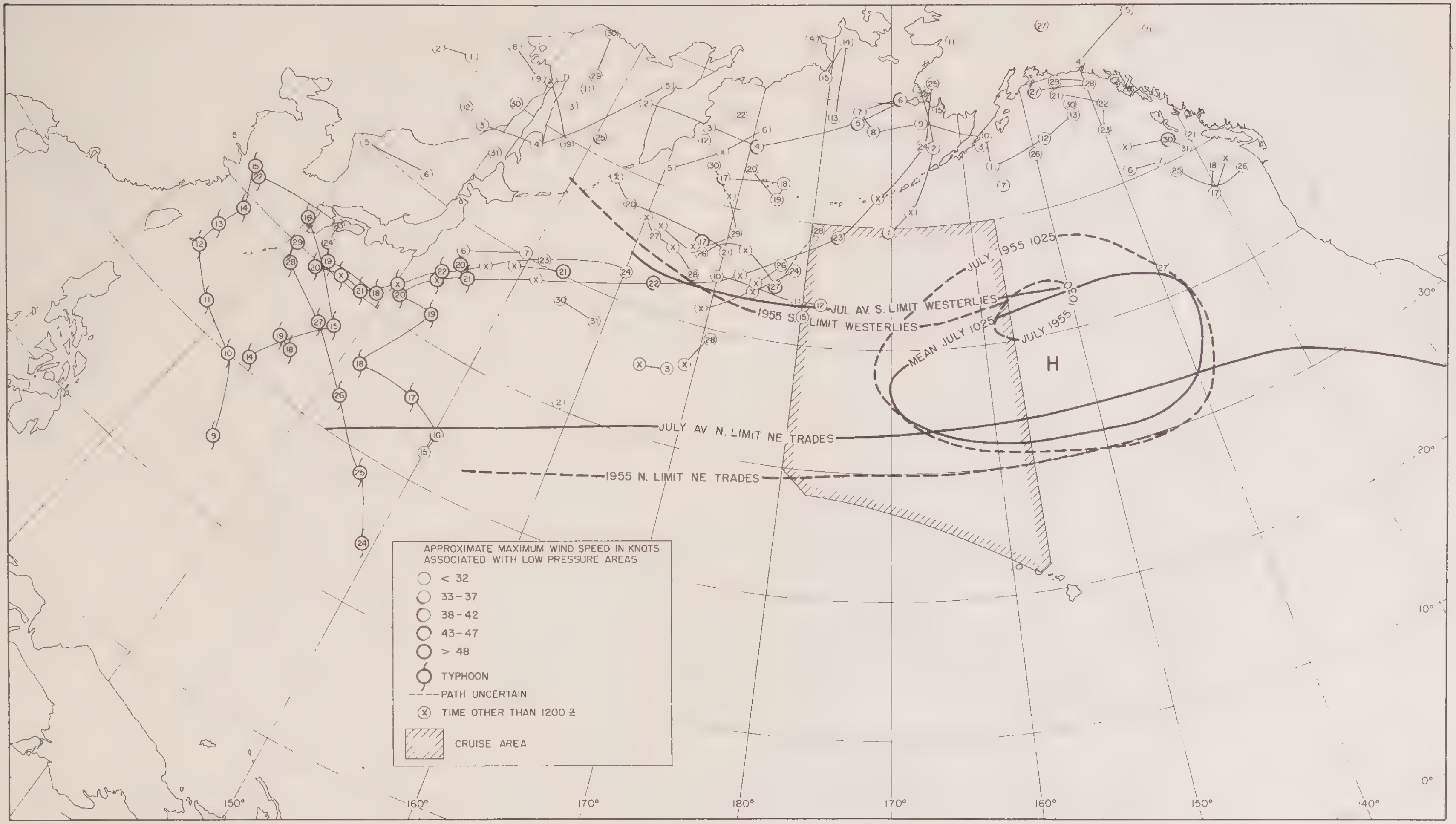

JULY 1955 1025
1030
JUL AV. S. LIMIT WESTERLIES
1955 S. LIMIT WESTERLIES
MEAN JULY 1025
JULY 1955
H
JULY AV N. LIMIT NE TRADES
1955 N. LIMIT NE TRADES
APPROXIMATE MAXIMUM WIND SPEED IN KNOTS ASSOCIATED WITH LOW PRESSURE AREAS
< 32
33-37
38-42
43-47
> 48
TYPHOON
PATH UNCERTAIN
TIME OTHER THAN 1200 Z
CRUISE AREA
150°
160°
170°
180°
170°
160°
150°
140°
30°
20°
10°
0°

Figure 143.--Normal (heavy solid lines) and mean July 1955 (broken lines) position of the Eastern North Pacific High; normal and 1955 mean monthly limits of the northeast trades and westerlies; tracks of centers of low pressure areas showing daily positions.

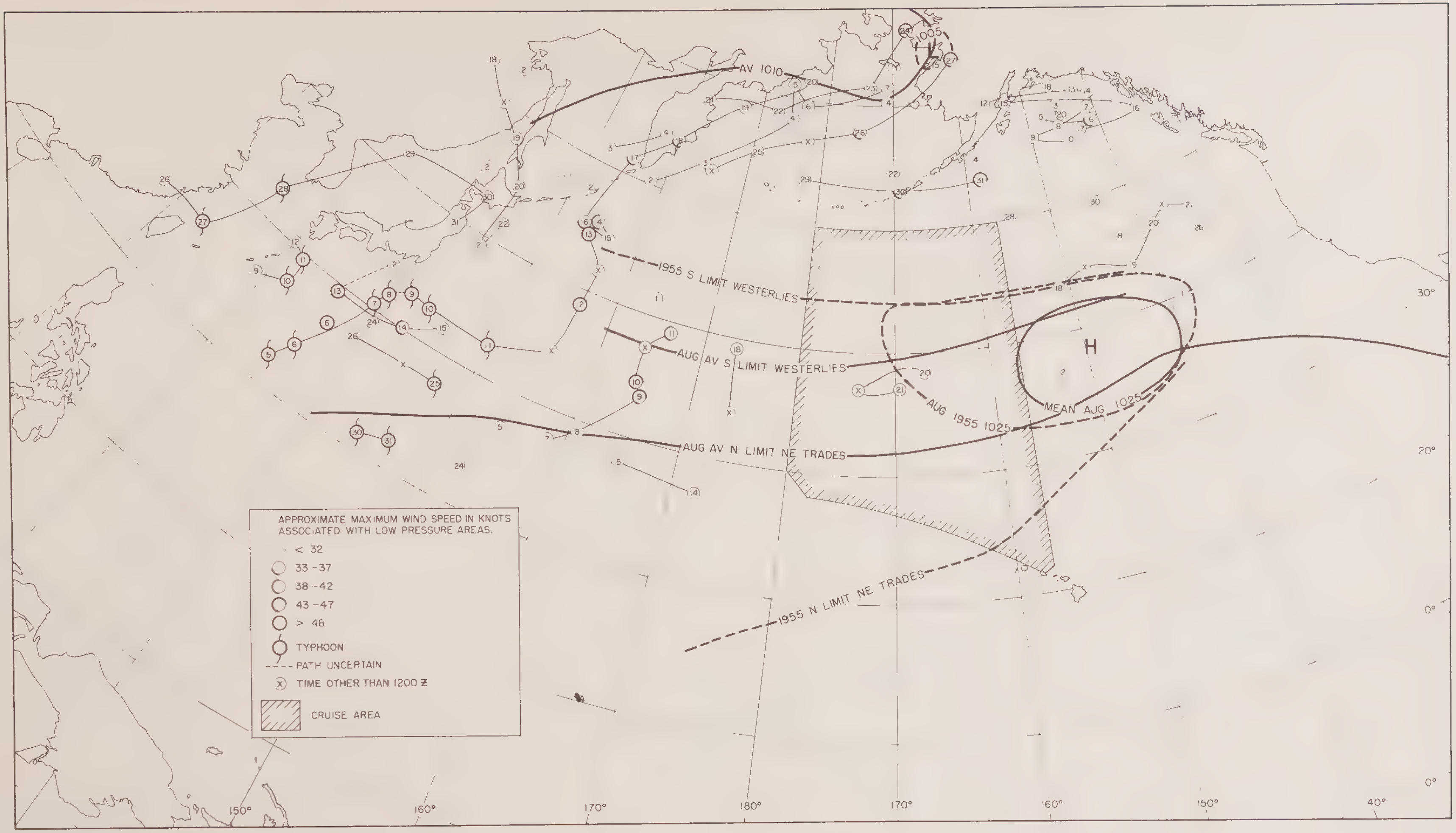

AV 1010
1005
1955 S LIMIT WESTERLIES
AUG AV S LIMIT WESTERLIES
AUG AV N LIMIT NE TRADES
1955 N LIMIT NE TRADES
AUG 1955 1025
MEAN AUG 1025
H
APPROXIMATE MAXIMUM WIND SPEED IN KNOTS ASSOCIATED WITH LOW PRESSURE AREAS.
< 32
33 - 37
38 - 42
43 - 47
> 48
TYPHOON
PATH UNCERTAIN
TIME OTHER THAN 1200 Z
CRUISE AREA
30°
20°
0°
0°
150°
160°
170°
180°
170°
160°
150°
40°

Figure 144.--Normal (heavy solid lines) and mean August 1955 (broken lines) position of the Eastern North Pacific High; normal and 1955 mean monthly limits of the northeast trades and westerlies; tracks of centers of low pressure areas showing daily positions.

NOTES ON TABLE 1, TABULATED OCEANOGRAPHIC DATA, CHG 17

Where more than one cast was made on a station, they are divided in the observed data by a horizontal line, and the cast number indicated by Roman numerals.

Weather is recorded in the ww (present weather) code given in the U. S. Weather Bureau circular M, eighth edition, Manual of Marine Meteorological Observations. Cloud cover is in tenths of the sky.

Wind velocity was measured with an anemometer approximately 8 meters above the sea surface. The direction (given to the nearest 10°) is that from which the wind was blowing, measured through 360° from north.

The following abbreviations, when appended to values or lines in the tabulated data have he following meanings:

Q -- The value seems questionable, but was used in construction of the station curve.

P -- The value is poor, and while carried was not used in drawing the station curve.

NG -- The value is obviously in error, and was dropped from the tabulations.

Table 1.--Oceanographic station data

STATION 1

M/V Charles H. Gilbert: Cruise 17, 22°30'N., 159°58'W., September 19, 1954. Messenger time: 0245 GCT. Weather 02, cloud coverage 4. Wind: 070°, 16 kt. Sea: 5-8 ft. Wire angle: 35°. BT slide: 2

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	26.58	35.07	22.93	4.25	- *
22	26.58	35.08	22.93	3.97	-
43	25.98	35.12	23.15	3.69	-
86	22.66	35.25	24.24	3.89	-
129	20.96	35.30	24.75	3.85	-
172	19.67	35.21	25.03	2.21 a/	-
263	14.21	34.45	25.74	3.02	-
349	10.42	34.20	26.27	3.91	-
445	08.57	34.13	26.52	3.98	-
528	06.94	34.09	26.73	4.35	-
724	05.17	34.27	27.10	0.98	-
921	04.58	34.43	27.29	1.62	-
1115	03.96	34.51	27.42	NS	-

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	26.58	35.07	22.93	0.000	1.878
10	26.58	35.07	22.93	0.049	1.829
20	26.58	35.08	22.93	0.099	1.779
30	26.52	35.08	22.95	0.148	1.730
50	24.70	35.18	23.59	0.241	1.637
75	23.65	35.21	23.92	0.345	1.533
100	21.93	35.28	24.47	0.440	1.438
150	20.40	35.28	24.89	0.605	1.273
200	17.85	34.95	25.29	0.753	1.125
250	14.60	34.49	25.68	0.881	0.997
300	12.40	34.29	25.98	0.993	0.885
400	09.42	34.16	26.41	1.184	0.694
500	07.38	34.09	26.67	1.342	0.536
600	06.08	34.14	26.89	1.478	0.400
700	05.29	34.24	27.06	1.595	0.283
800	04.88	34.34	27.19	1.698	0.180
1000	04.31	34.47	27.35	1.878	0.000

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* Due to malfunctioning colorimeter, PO_4-P samples could not be analyzed.

Table 1.--Oceanographic station data (cont'd)

STATION 2

M/V Charles H. Gilbert: Cruise 17, 24°12'N., 159°59'W., September 19, 1954. Messenger time: first cast 1806 GCT, second cast 1844 GCT. Weather: 02, cloud coverage 3. Wind: 090°, 16 kt. Sea: 1-3 ft. Wire angle: first cast 18°, second cast 19°. BT slide: 6

OBSERVED

	DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
I	0	25.64	35.26	23.36	4.30	- *
	20	25.64	35.26	23.36	4.38	-
	58	23.68	35.41	24.06	4.96	-
	96	21.78	NS	-	4.85	-
	145	19.82	35.19	24.97	4.53	-
	193	18.20	35.01	25.25	4.23	-
II	389	11.36	34.23	26.13	4.37	-
	489	08.42	34.13	26.55	3.60	-
	596	06.20	34.09	26.83	2.22	-
	688	05.50	34.25	27.04	0.98	-
	907	04.39	34.43	27.31	0.91	-
	1115	03.78	34.52	27.45	1.14	-
	PT	-	-	-	-	-

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	25.64	35.26	23.36	0.000	1.898
10	25.64	35.26	23.36	0.045	1.853
20	25.64	35.26	23.36	0.091	1.807
30	25.64	35.26	23.36	0.136	1.762
50	25.64	35.26	23.36	0.227	1.671
75	22.64	35.36	24.33	0.329	1.569
100	21.56	35.32	24.60	0.417	1.481
150	19.55	35.16	25.02	0.576	1.322
200	18.00	34.97	25.27	0.721	1.177
250	15.28	34.56	25.59	0.852	1.046
300	13.42	34.36	25.83	0.971	0.927
400	11.08	34.22	26.17	1.180	0.718
500	08.17	34.11	26.57	1.355	0.543
600	06.16	34.10	26.84	1.498	0.400
700	05.42	34.26	27.06	1.618	0.280
800	04.88	34.34	27.19	1.721	0.177
1000	04.06	34.47	27.38	1.898	0.000

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* Due to malfunctioning colorimeter, PO_4-P samples could not be analyzed.

Table 1.--Oceanographic station data (cont'd)

STATION 3

M/V Charles H. Gilbert: Cruise 17, 25°35'N., 159°52'W., September 20, 1954. Messenger time: 0736 GCT. Weather: 02, cloud coverage 1. Wind: 040°, 8 kt. Sea: 1-3 ft. Wire angle: 25°. BT slide: 9

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	25.14	35.53	23.72	4.94	0.23
23	NG	35.57	-	4.92	0.24
41	25.00	35.57	23.79	4.67	0.24
78	21.92	35.39	24.56	5.22	0.23
138	19.15	35.17	25.13	4.80	0.27
203	16.58	34.74	25.43	4.50	0.52
305	13.14	34.34	25.87	3.97	0.72
412	10.44	34.18	26.26	4.44	1.01
480	08.52	34.09	26.50	3.50	1.54
514	-	-	-	-	-
616	06.23	34.04	26.79	2.46	2.18
818	04.63	34.23	27.13	0.62	2.59
1024	03.80	34.42	27.37	1.05	2.74
1220	03.29	34.51	27.49	1.22	2.81

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	25.14	35.53	23.72	0.000	1.876
10	25.10	35.55	23.75	0.042	1.834
20	25.08	35.56	23.76	0.083	1.793
30	25.05	35.56	23.77	0.125	1.751
50	24.90	35.57	23.82	0.207	1.669
75	21.95	35.39	24.55	0.302	1.574
100	20.70	35.31	24.83	0.384	1.492
150	18.77	35.12	25.19	0.534	1.342
200	16.80	34.77	25.40	0.671	1.205
250	14.61	34.48	25.67	0.797	1.079
300	13.28	34.35	25.85	0.913	0.963
400	10.82	34.21	26.21	1.120	0.756
500	08.42	34.08	26.51	1.296	0.580
600	06.47	34.04	26.76	1.446	0.430
700	05.41	34.11	26.94	1.575	0.301
800	04.78	34.22	27.10	1.688	0.188
1000	03.88	34.40	27.34	1.876	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 4

M/V *Charles H. Gilbert*: Cruise 17, 27°00'N., 160°00'W., September 20, 1954. Messenger time: 2015 GCT. Weather: 02, cloud coverage 5. Wind: 040°, 10 kt. Sea: 1-3 ft. Wire angle: 15°. BT slide: 14

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	25.53	35.34	23.45	4.65	0.31
25	25.50	35.34	23.46	4.66	0.33
56	25.49	35.35	23.47	4.56	0.28
86	23.30	35.35	24.13	4.43	0.31
132	21.71	35.37	24.60	4.26	0.25
222	17.87	34.96	25.29	4.14	0.38
333	13.04	34.36	25.90	4.62	0.72
449	09.76	34.14	26.34	4.33	1.32
560	08.01	34.09	26.58	3.64	1.61
671	06.12	34.07	26.82	2.30	2.31
888	04.38	34.31	27.22	0.98	2.68
1105	03.68	34.43	27.39	1.08	2.53
1311	03.28	34.51	27.49	1.31	2.82

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	25.53	35.34	23.46	0.000	2.004
10	25.53	35.34	23.46	0.044	1.960
20	25.53	35.34	23.46	0.089	1.915
30	25.52	35.34	23.46	0.133	1.871
50	25.49	35.35	23.48	0.222	1.782
75	23.80	35.35	23.99	0.327	1.677
100	22.70	35.36	24.31	0.422	1.582
150	20.82	35.32	24.81	0.594	1.410
200	18.82	35.10	25.16	0.746	1.258
250	16.50	34.74	25.45	0.884	1.120
300	14.33	34.48	25.73	1.008	0.996
400	10.82	34.20	26.20	1.221	0.783
500	08.90	34.11	26.46	1.400	0.604
600	07.37	34.07	26.66	1.558	0.446
700	05.75	34.09	26.89	1.695	0.309
800	04.83	34.21	27.09	1.812	0.192
1000	03.99	34.38	27.32	2.004	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 5

M/V Charles H. Gilbert: Cruise 17, 28°28'N., 159°59'W., September 21, 1954. Messenger time: 0937 GCT. Weather: 02, cloud coverage not recorded. Wind: 100°, 10 kt. Sea: 1-3 ft. Wire angle: 06°. BT slide: 17

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	25.04	35.55	23.76	4.77	0.22
27	24.98	35.52	23.76	4.84	0.21
57	22.76	35.30	24.25	5.06	0.21
116	18.08	34.92	25.21	5.12	0.24
173	15.59	34.58	25.54	4.92	0.39
230	13.46	34.43	25.88	4.65	0.68
346	10.99	34.22	26.19	4.80	0.99
463	08.69	NG	-	NG	NG
580	06.53	34.05	26.75	3.29	1.87
694	05.22	34.09	26.95	1.83	2.51
919	04.07	34.31	27.25	0.91	2.68
1136	03.56	34.45	27.45	0.74	2.71
1346	03.06	34.54	27.53	1.13	2.88

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	25.04	35.55	23.77	0.000	1.780
10	25.02	35.54	23.76	0.041	1.739
20	25.00	35.52	23.75	0.083	1.697
30	24.95	35.52	23.77	0.125	1.655
50	24.89	35.51	23.78	0.208	1.572
75	19.70	35.08	24.92	0.298	1.482
100	18.66	34.98	25.11	0.372	1.408
150	16.42	34.68	25.42	0.510	1.270
200	14.66	34.51	25.69	0.634	1.146
250	12.88	34.37	25.95	0.747	1.033
300	11.81	34.28	26.09	0.850	0.930
400	09.96	34.16	26.32	1.040	0.740
500	08.00	34.08	26.57	1.208	0.572
600	06.20	34.04	26.79	1.353	0.427
700	05.20	34.09	26.95	1.479	0.301
800	04.59	34.19	27.10	1.591	0.189
1000	03.81	34.37	27.33	1.780	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 6

M/V Charles H. Gilbert: Cruise 17, 30°03'N., 159°49'W., September 21, 1954. Messenger time: 2100 GCT. Weather: 02, cloud coverage 1. Wind: Calm. Sea: <1 ft. Wire angle: 07°. BT slide: 21

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	24.82	35.57	23.85	4.46	0.02
26	24.47	35.57	23.95	4.51	0.01
57	22.00	35.17	24.36	4.97	0.09
114	17.26	34.74	25.26	5.36	0.13
172	15.21	34.52	25.58	4.72	0.35
226	13.60	34.40	25.82	4.42	0.59
343	11.12	34.22	26.17	4.31	0.83
463	08.71	NG	-	NG	NG
576	06.58	34.02	26.73	3.38	1.52
693	05.00	34.07	26.96	1.81	2.21
915	03.86	34.25	27.23	0.95	2.03
1134	03.35	34.43	27.42	0.70	2.13
1345	03.07	34.40	27.42	0.92	1.99

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	24.82	35.57	23.85	0.000	1.769
10	24.58	35.57	23.92	0.040	1.729
20	24.50	35.57	23.94	0.080	1.689
30	24.45	35.57	23.96	0.120	1.649
50	23.68	35.45	24.10	0.198	1.571
75	19.70	34.97	24.84	0.286	1.483
100	17.69	34.78	25.20	0.360	1.409
150	16.18	34.62	25.43	0.495	1.274
200	14.19	34.45	25.74	0.618	1.151
250	13.12	34.37	25.90	0.731	1.038
300	12.05	34.29	26.05	0.836	0.933
400	10.00	34.16	26.32	1.028	0.741
500	08.00	34.07	26.56	1.196	0.573
600	06.20	34.02	26.78	1.342	0.427
700	04.96	34.07	26.97	1.469	0.300
800	04.38	34.15	27.09	1.581	0.188
1000	03.60	34.35	27.33	1.769	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 7

M/V Charles H. Gilbert: Cruise 17, 31°29'N., 159°50'W., September 22, 1954. Messenger time: 1008 GCT. Weather: 02, clear. Wind: calm. Sea: <1 ft. Wire angle: 05°. BT slide: 26

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σt	O_2 (ml/l)	PO_4-P (μg at/l)
0	24.38	34.85	23.44	4.71	0.01
16	24.12	34.87	23.53	4.41	0.07
32	19.60	34.61	24.59	5.36	0.13
69	15.89	34.52	25.42	5.76	0.16
141	14.04	34.43	25.75	4.65	0.61
217	13.00	34.38	25.93	4.55	0.68
321	11.36	34.29	26.18	4.39	0.88
431	09.76	NG	-	NG	NG
538	07.81	34.05	26.58	3.82	1.49
649	05.98	34.04	26.82	2.98	1.88
866	04.12	34.16	26.13	1.02	2.20
1075	03.54	34.34	27.33	0.58	2.27
1289	03.05	34.43	27.45	0.86	2.56

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σt	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	24.38	34.85	23.44	0.000	1.726
10	24.21	34.86	23.49	0.044	1.682
20	24.02	34.87	23.56	0.088	1.638
30	23.60	34.84	23.66	0.131	1.595
50	16.90	34.55	25.21	0.201	1.525
75	15.64	34.51	25.47	0.268	1.458
100	14.82	34.47	25.62	0.330	1.396
150	13.99	34.42	25.76	0.447	1.279
200	13.24	34.39	25.89	0.558	1.168
250	12.48	34.35	26.01	0.664	1.062
300	11.68	34.31	26.13	0.765	0.961
400	10.22	34.22	26.33	0.953	0.773
500	08.52	34.10	26.51	1.123	0.603
600	06.66	34.04	26.73	1.275	0.451
700	05.40	34.05	26.90	1.407	0.319
800	04.57	34.10	27.03	1.525	0.201
1000	03.72	34.28	27.26	1.726	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 8

M/V Charles H. Gilbert: Cruise 17, 32°57'N., 159°55'W., September 22, 1954. Messenger time: 2143 GCT. Weather: 02, cloud coverage 1. Wind: 300°, 6 kt. Sea: <1 ft. Wire angle: 00°. BT slide: 29

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	23.64	34.74	23.57	4.45	0.22
21	24.18	35.10	23.68	4.26	0.14
42	18.85	34.58	24.76	5.18	0.20
83	15.62	34.49	25.46	5.24	0.21
151	13.48	34.40	25.85	4.70	0.60
214	12.30	34.34	26.04	4.61	0.81
319	10.99	34.25	26.22	4.44	0.95
431	09.11	NG	-	NG	NG
537	07.26	34.04	26.65	3.60	1.69
648	05.54	33.98	26.82	2.58	2.14
864	04.08	34.16	27.13	0.79	2.31
1073	03.39	34.34	27.34	0.60	2.14
1286	02.99	34.45	27.47	0.24	2.71

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	23.64	34.74	23.57	0.000	1.684
10	23.90	34.86	23.59	0.043	1.641
20	24.17	35.09	23.68	0.086	1.598
30	24.10	35.10	23.71	0.128	1.556
50	17.63	34.55	25.04	0.200	1.484
75	16.10	34.51	25.37	0.270	1.414
100	14.85	34.47	25.62	0.333	1.351
150	13.50	34.40	25.85	0.448	1.236
200	12.55	34.35	26.00	0.555	1.129
250	11.77	34.31	26.12	0.656	1.028
300	11.19	34.27	26.19	0.752	0.932
400	09.67	34.17	26.38	0.934	0.750
500	07.88	34.07	26.58	1.098	0.586
600	06.20	33.99	26.75	1.245	0.439
700	05.01	34.02	26.92	1.375	0.309
800	04.35	34.12	27.07	1.489	0.195
1000	03.60	34.29	27.28	1.684	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 9

M/V Charles H. Gilbert: Cruise 17, 34°29'N., 160°08'W., September 23, 1954. Messenger time: 1018 GCT. Weather: 02, clear. Wind: 240°, 18 kt. Sea: 3-5 ft. Wire angle: 31°. BT slide: 33

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
4	23.60	34.69	23.55	4.31	0.28
21	23.60	34.69	23.55	4.49	0.22
46	21.20	34.58	24.14	5.58	0.20
81	14.80	34.42	25.59	6.12	0.24
145	12.72	34.36	25.97	5.11	0.59
206	11.92	34.31	26.09	5.24	0.71
311	10.26	34.18	26.29	5.42	0.88
420	08.95	34.14	26.47	4.76	1.17
525	07.33	34.05	26.64	4.02	1.68
631	05.48	34.02	26.86	2.80	2.09
838	04.06	34.20	27.17	0.98	2.52
1047	03.31	34.36	27.37	0.45	2.46
1251	02.91	34.43	27.46	0.30	2.67

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	23.60	34.69	23.55	0.000	1.642
10	23.60	34.69	23.55	0.044	1.598
20	23.60	34.69	23.55	0.087	1.555
30	23.60	34.69	23.55	0.131	1.511
50	19.80	34.55	24.49	0.209	1.433
75	15.10	34.43	25.53	0.284	1.358
100	14.00	34.40	25.74	0.343	1.299
150	12.61	34.35	25.99	0.452	1.190
200	11.98	34.32	26.08	0.553	1.089
250	11.30	34.26	26.16	0.651	0.991
300	10.48	34.20	26.26	0.745	0.897
400	09.18	34.15	26.44	0.920	0.722
500	07.73	34.07	26.60	1.079	0.563
600	06.00	34.01	26.79	1.222	0.420
700	04.82	34.08	26.99	1.347	0.295
800	04.25	34.16	27.11	1.456	0.186
1000	03.44	34.33	27.33	1.642	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 10

M/V Charles H. Gilbert: Cruise 17, 38°54'N., 160°07'W., September 24, 1954. Messenger time: 2206 GCT. Weather: 60, cloud coverage 9. Wind: 060°, 10 kt. Sea: 1-3 ft. Wire angle: 06°. BT slide: 43

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	22.22	34.14	23.52	5.45	0.21
15	22.22	34.16	23.54	5.28	0.20
31	18.23	34.14	24.58	6.80	0.16
57	12.50	34.23	25.92	5.67	0.57
110	11.44	34.20	26.09	5.65	0.70
165	10.82	34.22	26.22	5.42	0.86
227	10.16	34.18	26.31	4.04	0.92
340	08.94	34.14	26.47	3.09	1.15
457	07.22	34.04	26.65	3.09	1.60
572	05.54	34.02	26.86	2.96	2.03
681	04.65	34.09	27.02	1.76	2.31
903	03.81	34.23	27.21	0.73	2.49
1126	03.17	34.36	27.38	0.33	2.84

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	22.22	34.14	23.52	0.000	1.499
10	22.22	34.15	23.53	0.044	1.455
20	22.22	34.16	23.54	0.087	1.412
30	19.80	34.14	24.18	0.128	1.371
50	13.20	34.22	25.77	0.188	1.311
75	11.98	34.23	26.01	0.241	1.258
100	11.60	34.20	26.06	0.291	1.208
150	11.00	34.22	26.19	0.388	1.111
200	10.45	34.20	26.27	0.480	1.019
250	09.88	34.18	26.35	0.568	0.931
300	09.39	34.16	26.42	0.653	0.846
400	08.10	34.10	26.57	0.814	0.685
500	06.55	34.02	26.73	0.961	0.538
600	05.23	34.04	26.91	1.091	0.408
700	04.55	34.12	27.05	1.207	0.292
800	04.15	34.18	27.14	1.311	0.188
1000	03.52	34.29	27.29	1.499	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 11

M/V Charles H. Gilbert: Cruise 17, 42°07'N., 159°59'W., September 26, 1954. Messenger time: 2356 GCT. Weather: 02, cloud coverage 4. Wind: 340°, 15 kt. Sea: 1-3 ft. Wire angle: 35°. BT slide: 49

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	19.00	33.75	24.09	5.50	0.27
17	18.95	33.75	24.10	5.16	0.27
31	18.82	33.78	24.16	5.24	0.28
60	11.87	33.78	25.68	6.74	0.57
94	09.85	33.89	26.13	6.25	0.84
137	08.92	33.93	26.31	6.05	0.98
188	08.70	34.04	26.43	5.68	1.07
283	07.70	34.00	26.55	5.24	1.15
385	06.28	34.00	26.75	4.36	1.55
480	05.18	34.07	26.94	2.72	2.13
579	04.59	NG	-	NG	NG
774	03.84	34.20	27.19	0.88	2.53
979	03.27	34.33	27.35	0.55	2.86

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	19.00	33.75	24.09	0.000	1.360
10	18.98	33.75	24.09	0.038	1.322
20	18.90	33.76	24.12	0.077	1.283
30	18.83	33.77	24.15	0.115	1.245
50	12.38	33.78	25.59	0.177	1.183
75	10.65	33.84	25.96	0.233	1.127
100	09.64	33.90	26.17	0.282	1.078
150	08.81	33.96	26.36	0.372	0.988
200	08.65	34.04	26.44	0.455	0.905
250	08.08	34.02	26.51	0.535	0.825
300	07.47	34.00	26.59	0.612	0.748
400	06.08	34.01	26.78	0.754	0.606
500	04.99	34.08	26.97	0.877	0.483
600	04.47	34.13	27.07	0.988	0.372
700	04.07	34.17	27.14	1.091	0.269
800	03.78	34.22	27.21	1.187	0.173
1000	03.23	34.34	27.36	1.360	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 12

M/V *Charles H. Gilbert*: Cruise 17, 43°42'N., 160°00'W., September 27, 1954. Messenger time: 1331 GCT. Weather: 02, clear. Wind: 100°, 14 kt. Sea: 1-3 ft. Wire angle: 03°. BT slide: 53

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	19.17	33.95	24.20	5.34	0.39
21	19.18	33.98	24.21	5.37	0.42
44	18.01	33.89	24.45	5.78	0.42
73	10.45	33.86	26.01	6.23	0.89
108	08.87	33.80	26.22	6.16	1.02
165	08.59	34.00	26.42	6.05	1.07
251	08.01	34.04	26.54	5.46	1.34
376	06.38	34.02	26.75	4.05	1.89
495	05.03	34.00	26.90	2.60	2.27
622	04.33	34.09	27.05	1.51	2.60
739	03.89	34.22	27.20	0.97	2.62
983	03.28	34.34	27.35	0.56	2.79
1215	02.87	34.42	27.45	0.41	2.91

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	19.17	33.95	24.20	0.000	1.350
10	19.17	33.96	24.20	0.037	1.313
20	19.18	33.98	24.22	0.075	1.275
30	19.15	33.98	24.22	0.112	1.238
50	12.60	33.87	25.62	0.173	1.177
75	10.40	33.86	26.01	0.228	1.122
100	08.95	33.80	26.21	0.276	1.074
150	08.67	33.96	26.38	0.364	0.986
200	08.38	34.03	26.48	0.446	0.904
250	08.02	34.04	26.54	0.525	0.825
300	07.57	34.04	26.60	0.601	0.749
400	06.01	34.01	26.79	0.741	0.609
500	05.00	34.00	26.91	0.868	0.482
600	04.43	34.06	27.02	0.984	0.366
700	04.00	34.18	27.16	1.088	0.262
800	03.70	34.26	27.25	1.182	0.168
1000	03.25	34.35	27.37	1.350	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 13

M/V Charles H. Gilbert: Cruise 17, 45°03'N., 163°43'W., October 1, 1954. Messenger time: 1926 GCT. Weather: 50, cloud coverage 8. Wind: 180°, 18 kt. Sea: 5-8 ft. Wire angle: 35°. BT slide: 65

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	15.53	33.06	24.39	6.11	0.69
13	15.51	33.12	24.44	6.38	0.77
27	15.51	33.08	24.41	6.68	0.75
44	08.69	33.37	25.91	7.04	1.07
84	06.80	33.40	26.21	6.72	1.20
142	06.39	33.57	26.39	6.29	1.18
214	06.33	33.86	26.63	5.45	1.34
321	05.38	33.87	26.76	3.73	1.99
424	04.69	33.98	26.92	2.35	2.20
532	04.27	34.05	27.02	1.68	2.51
637	03.90	34.13	27.13	1.05	2.60
856	03.40	34.27	27.29	0.68	2.41
NG	-	-	-	-	-

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	15.53	33.06	24.38	0.000	1.238
10	15.52	33.10	24.42	0.035	1.203
20	15.51	33.10	24.42	0.071	1.167
30	13.40	33.30	25.02	0.103	1.135
50	08.20	33.37	25.99	0.153	1.085
75	07.05	33.39	26.17	0.202	1.036
100	06.59	33.84	26.58	0.244	0.994
150	06.39	33.87	26.63	0.316	0.922
200	06.35	33.87	26.64	0.388	0.850
250	06.00	33.86	26.67	0.459	0.779
300	05.53	33.86	26.73	0.529	0.709
400	04.81	33.96	26.89	0.657	0.581
500	04.40	34.03	27.00	0.773	0.465
600	04.00	34.10	27.09	0.880	0.358
700	03.72	34.17	27.18	0.980	0.258
800	03.53	34.24	27.25	1.072	0.166
1000	03.15	34.36	27.38	1.238	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 14

M/V *Charles H. Gilbert*: Cruise 17, 43°47'N., 169°43'W., October 4, 1954. Messenger time: 0531 GCT. Weather: 02, cloud coverage 8. Wind: 330°, 3 kt. Sea: 3-5 ft. Wire angle: 18°. BT slide: 77

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	14.04	33.33	24.91	6.05	0.50
20	14.00	33.33	24.92	6.20	0.52
35	09.52	33.66	26.01	6.08	0.75
56	08.64	33.71	26.18	5.20	0.81
85	07.79	33.75	26.35	3.86	0.96
149	07.67	33.89	26.47	3.17	0.99
217	06.62	33.89	26.62	2.99	1.24
326	05.48	33.93	26.79	2.56	1.82
441	04.67	34.02	26.96	2.38	2.10
550	04.28	34.11	27.07	1.70	2.31
661	03.90	34.18	27.17	1.13	2.38
873	03.35	34.31	27.32	0.71	2.54
1089	02.95	34.42	27.45	0.55	2.65

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	14.04	33.33	24.91	0.000	1.229
10	14.02	33.33	24.91	0.031	1.198
20	14.00	33.33	24.92	0.061	1.168
30	13.99	33.34	24.93	0.091	1.138
50	09.00	33.69	26.11	0.141	1.088
75	07.92	33.73	26.31	0.187	1.042
100	07.77	33.76	26.36	0.230	0.999
150	07.66	33.89	26.47	0.312	0.917
200	06.84	33.90	26.60	0.388	0.841
250	06.21	33.90	26.68	0.461	0.768
300	05.72	33.91	26.75	0.529	0.700
400	04.91	33.98	26.90	0.656	0.573
500	04.46	34.06	27.01	0.772	0.457
600	04.08	34.14	27.12	0.877	0.352
700	03.79	34.20	27.19	0.975	0.254
800	03.52	34.25	27.26	1.066	0.163
1000	03.06	34.38	27.41	1.229	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 15

M/V *Charles H. Gilbert*: Cruise 17, 42°14'N., 169°53'W., October 4, 1954. Messenger time: 1834 GCT. Weather: 50, cloud coverage 8. Wind: 140°, 13 kt. Sea: 1-3 ft. Wire angle: 26°. BT slide: 80

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	15.16	33.48	24.79	5.40	0.66
18	15.16	33.49	24.80	5.49	0.67
32	11.42	33.98	25.92	6.30	0.94
50	10.33	34.02	26.15	5.80	1.30
77	09.53	34.02	26.28	5.84	1.39
137	09.12	34.11	26.42	5.60	1.26
201 *	08.12	34.02	26.51	5.37	1.45
303	06.84	33.96	26.64	4.61	1.68
409	05.48	33.95	26.81	3.70	2.15
511	04.76	34.00	26.93	2.21	2.63
614	04.28	34.13	27.09	1.49	2.71
820	03.62	34.27	27.27	0.82	2.65
1032	02.92	34.38	27.42	0.63	2.77

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	15.16	33.48	24.79	0.000	1.281
10	15.16	33.49	24.79	0.032	1.249
20	15.18	33.54	24.83	0.063	1.218
30	15.15	33.72	24.97	0.094	1.187
50	10.33	34.02	26.15	0.143	1.138
75	09.55	34.02	26.28	0.188	1.093
100	09.30	34.09	26.38	0.231	1.050
150	08.99	34.11	26.44	0.314	0.967
200	08.14	34.02	26.50	0.394	0.887
250	07.50	33.99	26.58	0.471	0.810
300	06.90	33.96	26.64	0.545	0.736
400	05.58	33.95	26.80	0.683	0.598
500	04.81	33.99	26.92	0.808	0.473
600	04.32	34.11	27.07	0.921	0.360
700	04.00	34.19	27.16	1.022	0.259
800	03.72	34.25	27.24	1.116	0.165
1000	03.00	34.37	27.40	1.281	0.000

* This bottle flipped almost upright by a heavy roll as it broke the surface, but data look good.

Table 1.--Oceanographic station data (cont'd)

STATION 16

M/V Charles H. Gilbert: Cruise 17, 41°00'N., 169°47'W., October 5, 1954. Messenger time: 0726 GCT. Weather: 02, cloud coverage not recorded. Wind: 210°, 22 kt. Sea: 3-5 ft. Wire angle: 26°. BT slide: 83

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 * (ml/l)	PO_4-P (µg at/l)
0	16.53	33.95	24.84	5.02	0.33
19	16.52	33.93	24.83	5.09	0.35
42	15.92	33.86	24.91	5.48	0.38
54	11.33	34.13	26.06	5.76	0.81
108	09.86	34.09	26.29	5.76	1.00
162	09.52	34.14	26.38	5.61	1.06
218	08.89	34.11	26.46	5.40	1.14
327	07.51	34.02	26.60	4.94	1.54
436	05.82	33.96	26.78	3.46	1.90
551	04.81	34.02	26.94	2.61	2.40
658	04.40	34.11	27.06	1.91	2.64
882	03.64	34.25	27.25	0.88	2.74
1112	03.08	34.38	27.40	0.57	2.95

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	16.53	33.95	24.84	0.000	1.355
10	16.53	33.94	24.83	0.031	1.324
20	16.52	33.93	24.83	0.063	1.292
30	16.25	33.89	24.86	0.094	1.261
50	11.41	34.11	26.03	0.145	1.210
75	10.83	34.13	26.15	0.194	1.161
100	10.20	34.09	26.23	0.240	1.115
150	09.82	34.10	26.30	0.330	1.025
200	09.03	34.12	26.45	0.414	0.941
250	08.51	34.09	26.50	0.495	0.860
300	07.87	34.04	26.56	0.573	0.782
400	06.30	33.96	26.71	0.719	0.636
500	05.20	33.98	26.87	0.851	0.504
600	04.60	34.07	27.01	0.969	0.386
700	04.22	34.14	27.10	1.077	0.278
800	03.90	34.21	27.19	1.177	0.178
1000	03.34	34.31	27.33	1.355	0.000

* Order of O_2 samples is unsure, but appears correct.

Table 1.--Oceanographic station data (cont'd)

STATION 17

M/V Charles H. Gilbert: Cruise 17, 38°41'N., 169°57'W., October 6, 1954. Messenger time: 0708 GCT. Weather: 02, clear. Wind: 200°, 05 kt. Sea: 1-3 ft. Wire angle: 12°. BT slide: 88

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	18.12	33.78	24.33	5.24	0.34
26	18.10	33.77	24.33	5.61	0.44
45	14.44	34.31	25.58	6.36	0.56
65	13.10	34.36	25.90	5.74	0.63
118	12.03	34.31	26.07	5.34	0.92
166	10.99	34.22	26.19	5.29	0.96
230	10.12	34.20	26.33	5.03	1.06
354	07.96	34.04	26.55	5.01	1.38
466	06.27	33.95	26.71	4.17	1.79
585	05.00	33.98	26.89	2.65	2.32
698	04.37	34.09	27.05	1.80	2.67
928	03.64	34.25	27.25	0.80	2.66
1162	03.05	34.36	27.39	0.58	2.73

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	18.12	33.78	24.33	0.000	1.469
10	18.12	33.78	24.33	0.036	1.433
20	18.11	33.77	24.32	0.072	1.397
30	18.10	33.77	24.33	0.108	1.361
50	13.93	34.35	25.72	0.168	1.301
75	12.86	34.34	25.93	0.223	1.246
100	12.42	34.33	26.01	0.274	1.195
150	11.25	34.24	26.16	0.373	1.096
200	10.50	34.21	26.27	0.465	1.004
250	09.81	34.17	26.36	0.553	0.916
300	08.96	34.10	26.44	0.638	0.831
400	07.20	33.99	26.62	0.795	0.674
500	05.82	33.95	26.77	0.937	0.532
600	04.88	33.99	26.91	1.065	0.404
700	04.33	34.10	27.06	1.180	0.289
800	03.99	34.17	27.15	1.283	0.186
1000	03.44	34.29	27.30	1.469	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 18

M/V Charles H. Gilbert: Cruise 17, 37°07'N., 170°05'W., October 7, 1954. Messenger time: 0528 GCT. Weather: 28, cloud coverage 9. Wind: calm. Sea: <1 ft. Wire angle: 03°. BT slide: 91

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	20.22	34.05	24.00	4.83	0.35
15	19.42	34.07	24.22	4.94	0.30
31	19.40	34.07	24.23	4.79	0.26
54	14.64	34.45	25.64	5.47	0.38
75	13.64	34.43	25.84	4.90	0.71
149	12.48	34.40	26.05	4.92	0.76
237	11.24	34.31	26.21	4.55	0.93
365	09.01	34.13	26.45	4.90	1.30
483	07.16	34.00	26.63	4.45	1.59
605	05.45	33.98	26.84	3.03	2.23
728	04.56	34.07	27.01	1.91	2.57
971	03.69	34.23	27.23	0.75	2.65
1209	03.03	34.36	27.39	0.41	2.83

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	20.22	34.05	24.00	0.000	1.561
10	19.52	34.06	24.19	0.038	1.523
20	19.41	34.07	24.23	0.076	1.485
30	19.40	34.07	24.23	0.113	1.448
50	15.20	34.44	25.52	0.175	1.386
75	13.64	34.43	25.84	0.233	1.328
100	13.12	34.42	25.94	0.287	1.274
150	12.47	34.40	26.05	0.389	1.172
200	11.80	34.36	26.15	0.488	1.073
250	11.00	34.29	26.24	0.582	0.979
300	10.19	34.23	26.34	0.672	0.889
400	08.48	34.08	26.50	0.840	0.721
500	06.87	33.99	26.66	0.994	0.567
600	05.50	33.98	26.83	1.132	0.429
700	04.70	34.05	26.98	1.254	0.307
800	04.22	34.12	27.09	1.365	0.196
1000	03.60	34.25	27.25	1.561	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 19

M/V Charles H. Gilbert: Cruise 17, 34°07'N., 170°12'W., October 8, 1954. Messenger time: 0629 GCT. Weather: 02, cloud coverage 3. Wind: 190°, 19 kt. Sea: 3-5 ft. Wire angle: 22°. BT slide: 97

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
4	22.35	34.42	23.70	4.22	- *
22	22.22	34.52	23.81	4.12	-
46	18.76	34.69	24.86	4.79	-
59	17.50	34.69	25.18	4.64	-
89	16.04	34.67	25.50	4.41	-
147	14.89	34.60	25.71	4.31	-
232	13.42	34.47	25.92	4.15	-
353	11.14	34.31	26.23	4.38	-
461	09.09	34.13	26.44	4.57	-
579	07.02	34.04	26.68	3.80	-
686	05.27	34.00	26.87	2.86	-
913	04.02	34.20	27.17	1.08	-
1141	03.02	34.34	27.38	0.56	-

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t (gm/l)	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	22.35	34.42	23.70	0.000	1.738
10	22.35	34.44	23.72	0.042	1.696
20	22.27	34.46	23.75	0.084	1.654
30	21.80	34.61	24.00	0.124	1.614
50	18.25	34.70	25.00	0.193	1.545
75	16.60	34.68	25.38	0.264	1.474
100	15.78	34.66	25.55	0.327	1.411
150	14.82	34.60	25.72	0.447	1.291
200	14.01	34.52	25.83	0.561	1.177
250	13.12	34.45	25.96	0.670	1.068
300	12.20	34.37	26.08	0.773	0.965
400	10.22	34.22	26.33	0.963	0.775
500	08.42	34.10	26.53	1.133	0.605
600	06.61	34.03	26.73	1.284	0.454
700	05.19	34.01	26.89	1.416	0.322
800	04.59	34.08	27.01	1.535	0.203
1000	03.59	34.26	27.26	1.738	0.000

* Colorimeter out of operation, no PO_4-P analyses stations No. 19 to No. 24.

Table 1.--Oceanographic station data (cont'd)

STATION 20

M/V Charles H. Gilbert: Cruise 17, 32°29'N., 170°17'W., October 8, 1954. Messenger time: 2000 GCT. Weather: 02, cloud coverage 1. Wind: 220°, 8 kt. Sea: <1 ft. Wire angle: 20°. BT slide: 101

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	23.17	34.78	23.74	3.99	- *
19	22.94	34.81	23.83	4.05	-
38	21.02	34.99	24.50	4.73	-
58	18.68	34.85	25.00	5.06	-
90	16.67	34.69	25.37	4.55	-
155	15.13	34.58	25.64	4.08	-
222	14.15	34.49	25.78	4.30	-
340	12.37	34.38	26.06	4.40	-
447	10.75	34.29	26.29	4.25	-
554	08.30	34.11	26.55	3.83	-
672	06.54	34.02	26.73	3.43	-
898	04.33	34.13	27.08	1.23	-
1126	03.04	34.29	27.34	0.54	-

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	23.17	34.78	23.74	0.000	1.840
10	23.08	34.79	23.77	0.042	1.798
20	22.92	34.81	23.83	0.083	1.757
30	22.90	34.82	23.85	0.123	1.717
50	19.22	34.88	24.89	0.195	1.645
75	17.60	34.76	25.20	0.269	1.571
100	16.25	34.66	25.45	0.336	1.504
150	15.20	34.59	25.63	0.460	1.380
200	14.45	34.52	25.74	0.579	1.261
250	13.70	34.46	25.85	0.692	1.148
300	12.95	34.42	25.97	0.801	1.039
400	11.48	34.33	26.19	1.003	0.837
500	09.55	34.21	26.43	1.185	0.655
600	07.48	34.08	26.65	1.345	0.495
700	06.20	34.01	26.77	1.489	0.351
800	05.18	33.98	26.87	1.622	0.218
1000	03.58	34.25	27.25	1.840	0.000

* See Station 19

Table 1.--Oceanographic station data (cont'd)

STATION 21

M/V Charles H. Gilbert: Cruise 17, 31°12'N., 170°10'W., October 9, 1954. Messenger time: 0651 GCT. Weather: 02, clear. Wind: 180°, 14 kt. Sea: 1-3 ft. Wire angle: 05°. BT slide: 103

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	23.78	34.81	23.55	4.47	- *
15	23.38	34.85	23.73	4.66	-
31	23.11	34.92	23.86	4.74	-
55	17.97	34.78	25.13	5.48	-
93	16.39	34.72	25.46	5.06	-
149	15.30	34.61	25.62	4.73	-
240	13.88	34.51	25.85	4.83	-
367	11.86	34.34	26.12	5.00	-
484	09.71	34.18	26.38	4.89	-
612	07.18	34.02	26.65	3.75	-
728	05.53	33.96	26.81	2.76	-
969	03.98	34.18	27.16	0.83	-
1206	03.03	34.36	27.39	0.38	-

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	23.78	34.81	23.58	0.000	1.829
10	23.42	34.84	23.71	0.043	1.786
20	23.32	34.86	23.76	0.084	1.745
30	23.15	34.91	23.84	0.126	1.703
50	18.25	34.80	25.08	0.195	1.634
75	16.86	34.74	25.37	0.265	1.564
100	16.20	34.70	25.49	0.330	1.499
150	15.29	34.61	25.63	0.453	1.376
200	14.46	34.55	25.76	0.571	1.258
250	13.72	34.50	25.88	0.684	1.145
300	12.98	34.44	25.98	0.791	1.038
400	11.27	34.29	26.19	0.993	0.836
500	09.40	34.16	26.42	1.175	0.654
600	07.40	34.03	26.62	1.337	0.492
700	05.80	33.96	26.78	1.481	0.348
800	04.90	34.01	26.92	1.610	0.219
1000	03.80	34.20	27.19	1.829	0.000

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* See Station 19

Table 1.--Oceanographic station data (cont'd)

STATION 22

M/V Charles H. Gilbert: Cruise 17, 30°00'N., 170°10'W., October 9, 1954. Messenger time: 1651 GCT. Weather: 02, cloud coverage 1. Wind: 090°, 8 kt. Sea: <1 ft. Wire angle: 34°. BT slide: 106

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	24.70	35.12	23.54	4.31	- *
17	24.40	35.07	23.59	4.23	-
29	24.76	35.41	23.74	4.45	-
42	22.00	35.23	24.41	4.86	-
71	19.87	35.23	24.99	4.74	-
118	18.13	34.97	25.23	4.46	-
194	15.53	34.65	25.60	4.56	-
297	13.80	34.49	25.85	4.81	-
393	11.50	34.29	26.15	4.32	-
495	10.19	34.23	26.34	4.28	-
591	07.57	34.07	26.63	3.63	-
811	04.85	34.09	26.99	1.66	-
1034	03.03	34.29	27.34	0.44	-

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D\,1000 - \Delta D$ (dyn. m)
00	24.70	35.12	23.54	0.000	1.884
10	24.41	35.07	23.59	0.043	1.841
20	24.63	35.27	23.68	0.086	1.798
30	24.75	35.40	23.74	0.128	1.756
50	21.10	35.23	24.66	0.203	1.681
75	19.70	35.22	25.03	0.281	1.603
100	18.59	35.03	25.17	0.354	1.530
150	16.90	34.81	25.41	0.491	1.393
200	15.40	34.63	25.62	0.617	1.267
250	14.61	34.56	25.74	0.737	1.147
300	13.70	34.48	25.87	0.851	1.033
400	11.40	34.28	26.16	1.060	0.824
500	10.08	34.22	26.35	1.247	0.637
600	07.40	34.06	26.64	1.411	0.473
700	06.15	34.03	26.79	1.554	0.330
800	05.00	34.08	26.97	1.681	0.203
1000	03.20	34.27	27.31	1.884	0.000

* See Station 19

Table 1.--Oceanographic station data (cont'd)

STATION 23

M/V Charles H. Gilbert: Cruise 17, 29°45'N., 172°05'W., October 10, 1954. Messenger time: 0548 GCT. Weather: 02, cloud coverage 1. Wind: 110°, 12 kt. Sea: 1-3 ft. Wire angle: 14°. BT slide: 109

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	24.99	35.16	23.48	4.07	- *
15	24.75	35.12	23.53	4.08	-
30	24.36	35.07	23.61	4.42	-
41	22.59	35.03	24.10	4.56	-
61	18.81	34.92	25.03	5.23	-
112	16.34	34.72	25.47	4.92	-
238	13.81	34.45	25.82	4.57	-
360	11.34	34.31	26.19	4.59	-
474	09.12	34.18	26.48	4.38	-
598	06.73	34.05	26.73	3.41	-
712	05.23	34.07	26.93	2.15	-
950	03.88	34.27	27.24	0.64	-
1182	03.25	34.45	27.44	0.58	-

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	24.99	35.16	23.49	0.000	1.774
10	24.82	35.13	23.52	0.044	1.730
20	24.60	35.10	23.56	0.088	1.686
30	24.36	35.07	23.61	0.131	1.643
50	19.52	34.95	24.87	0.205	1.569
75	18.10	34.86	25.16	0.279	1.495
100	16.80	34.76	25.40	0.348	1.426
150	15.50	34.63	25.59	0.474	1.300
200	14.51	34.51	25.72	0.594	1.180
250	13.58	34.44	25.86	0.708	1.066
300	12.59	34.38	26.01	0.815	0.959
400	10.52	34.26	26.30	1.010	0.764
500	08.60	34.14	26.53	1.181	0.593
600	06.65	34.05	26.74	1.331	0.443
700	05.38	34.06	26.91	1.463	0.311
800	04.60	34.14	27.06	1.579	0.195
1000	03.70	34.32	27.30	1.774	0.000

* See Station 19

Table 1.--Oceanographic station data (cont'd)

STATION 24

M/V Charles H. Gilbert: Cruise 17, 29°17'N., 173°54'W., October 10, 1954. Messenger time: 1824 GCT. Weather: 02, cloud coverage 2. Wind: 090°, 12 kt. Sea: 1-3 ft. Wire angle: 20°. BT slide: 112

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	24.86	35.17	23.53	3.76	- *
15	24.85	35.17	23.53	3.82	-
33	23.62	35.08	23.84	4.58	-
60	19.24	34.88	24.88	5.52	-
110	16.59	34.76	25.45	4.74	-
160	15.28	34.61	25.63	4.82	-
228	13.98	34.49	25.81	4.77	-
350	11.64	34.33	26.15	4.69	-
460	09.78	34.18	26.37	4.42	-
570	07.22	34.05	26.66	3.64	-
690	05.60	34.05	26.87	2.53	-
920	04.00	34.43	27.36	0.76	-
1150	03.30	34.40	27.40	0.63	-

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	24.86	35.17	23.53	0.000	1.767
10	24.86	35.17	23.53	0.044	1.723
20	24.85	35.17	23.54	0.087	1.680
30	24.08	35.10	23.71	0.130	1.637
50	19.73	34.90	24.78	0.204	1.563
75	18.54	34.85	25.04	0.281	1.486
100	16.88	34.78	25.39	0.351	1.416
150	15.62	34.65	25.58	0.478	1.289
200	14.61	34.54	25.72	0.598	1.169
250	13.58	34.46	25.88	0.711	1.056
300	12.61	34.39	26.02	0.818	0.949
400	10.82	34.27	26.26	1.015	0.752
500	08.85	34.11	26.47	1.191	0.576
600	06.70	34.03	26.72	1.345	0.422
700	05.50	34.06	26.89	1.479	0.288
800	04.75	34.30	27.17	1.591	0.176
1000	03.61	34.43	27.39	1.767	0.000

* See Station 19

Table 1.--Oceanographic station data (cont'd)

STATION 25

M/V Charles H. Gilbert: Cruise 17, 28°48'N., 178°18'W., October 15, 1954. Messenger time: 0850 GCT. Weather: 02, cloud coverage 6. Wind: 090°, 10 kt. Sea: 1-3 ft. Wire angle: 15°. BT slide: 114

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	25.32	35.16	23.39	5.05	0.21
20	25.34	35.16	23.38	5.06	0.23
40	23.40	35.05	23.88	5.30	0.15
60	21.22	34.87	24.35	5.53	0.14
91	17.81	34.72	25.12	5.44	0.22
142	16.20	34.67	25.47	4.12 Q	0.43
232	14.71	34.52	25.68	4.81	0.62
353	12.46	34.38	26.04	4.95	1.22
463	10.71	34.20	26.22	4.77	1.35
584	08.30	34.07	26.52	4.23	1.83
695	05.99	34.00	26.79	3.25	2.51
926	04.08	34.18	27.15	1.09	2.93
1158	03.33	34.36	27.36	0.55	3.27

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	25.32	35.16	23.39	0.000	1.932
10	25.33	35.16	23.38	0.045	1.887
20	25.34	35.16	23.38	0.090	1.842
30	25.30	35.16	23.39	0.135	1.797
50	22.28	34.95	24.12	0.219	1.713
75	19.40	34.78	24.77	0.307	1.625
100	17.40	34.71	25.22	0.382	1.550
150	16.05	34.66	25.49	0.515	1.417
200	15.22	34.57	25.61	0.640	1.292
250	14.40	34.50	25.74	0.759	1.173
300	13.48	34.44	25.88	0.873	1.059
400	11.70	34.30	26.12	1.083	0.849
500	10.02	34.14	26.30	1.275	0.657
600	07.99	34.05	26.55	1.446	0.486
700	05.90	34.00	26.80	1.593	0.339
800	04.96	34.05	26.95	1.721	0.211
1000	03.72	34.26	27.25	1.932	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 26

M/V Charles H. Gilbert: Cruise 17, 29°51'N., 179°45'E., October 16, 1954. Messenger time: 0120 GCT. Weather: 02, cloud coverage 1. Wind: 150°, 5 kt. Sea: <1 ft. Wire angle: 02°. BT slide: 119

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	25.08	34.99	23.33	4.72	0.13
16	24.70	34.99	23.45	4.83	0.15
31	24.46	34.99	23.52	4.86	0.01
47	20.25	34.79	24.55	5.71	0.09
89	17.02	NS	-	5.42	0.16
146	16.08	34.67	25.50	4.87	0.27
240	14.82	34.54	25.68	5.05	0.64
367	12.90	34.43	25.99	4.89	0.75
483	10.76	34.29	26.28	4.69	0.91
609	07.74	34.05	26.59	4.23	1.84
726	05.67	34.04	26.86	2.85	2.43
967	04.05	34.16	27.14	0.93	2.77
1204	03.34	34.38	27.38	0.78	3.14

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D\,1000 - \Delta D$ (dyn. m)
00	25.08	34.99	23.33	0.000	1.916
10	24.79	34.99	23.42	0.045	1.871
20	24.65	34.99	23.46	0.090	1.826
30	24.47	34.99	23.51	0.134	1.782
50	19.80	34.77	24.66	0.211	1.705
75	17.58	34.72	25.18	0.288	1.628
100	16.78	34.71	25.36	0.356	1.560
150	16.05	34.66	25.49	0.486	1.430
200	15.41	34.60	25.59	0.611	1.305
250	14.70	34.54	25.70	0.732	1.184
300	13.97	34.49	25.82	0.848	1.068
400	12.35	34.40	26.08	1.064	0.852
500	10.40	34.26	26.33	1.257	0.659
600	07.92	34.06	26.57	1.426	0.490
700	06.01	34.02	26.80	1.572	0.344
800	04.99	34.07	26.96	1.699	0.217
1000	03.90	34.19	27.17	1.916	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 27

M/V *Charles H. Gilbert*: Cruise 17, 31°30'N., 179°37'E., October 16, 1954. Messenger time: 1420 GCT. Weather: 02, cloud coverage 2. Wind: 180°, 04 kt. Sea: <1 ft. Wire angle: 07°. BT slide: 122

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	24.00	34.83	23.53	4.83	0.01
21	23.58	34.78	23.62	4.82	0.00
42	20.58	34.70	24.40	5.44	0.09
69	18.78	34.70	24.86	5.49	0.06
119	16.60	34.76	25.44	4.78	NS
171	16.05	34.70	25.53	4.72	0.35
240	15.31	34.63	25.64	4.69	0.53
366	13.38	34.45	25.91	4.79	0.89
478	11.36	34.34	26.21	4.37	1.04
606	08.54	34.09	26.50	3.52	1.65
720	05.81	33.98	26.79	1.29	2.37
959	04.08	34.18	27.15	0.72	3.13
1195	03.34	34.31	27.32	NS	3.37

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D\,1000 - \Delta D$ (dyn. m)
00	24.00	34.83	23.53	0.000	1.952
10	24.00	34.83	23.53	0.044	1.908
20	23.60	34.79	23.62	0.087	1.865
30	23.19	34.74	23.70	0.129	1.823
50	19.97	34.70	24.56	0.206	1.746
75	18.22	34.72	25.02	0.285	1.667
100	16.98	34.76	25.35	0.356	1.596
150	16.28	34.72	25.49	0.486	1.466
200	15.77	34.67	25.56	0.612	1.340
250	15.15	34.61	25.66	0.735	1.217
300	14.45	34.54	25.76	0.853	1.099
400	12.74	34.41	26.01	1.075	0.877
500	10.90	34.30	26.27	1.275	0.677
600	08.66	34.10	26.49	1.451	0.501
700	06.22	33.98	26.74	1.605	0.347
800	04.99	34.06	26.95	1.735	0.217
1000	03.94	34.20	27.18	1.952	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 28

M/V Charles H. Gilbert: Cruise 17, 32°59'N., 179°58'E., October 17, 1954. Messenger time: 0214 GCT. Weather: 02, cloud coverage 3. Wind: 080°, 22 kt. Sea: 1-3 ft. Wire angle: 26°. BT slide: 125

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	23.20	34.47	23.50	4.96	0.16
14	23.20	34.47	23.50	4.97	0.08
27	22.56	34.45	23.67	4.91	0.20
56	19.44	34.67	24.67	5.20	0.18
91	17.50	34.72	25.20	4.82	0.45
141	15.90	34.63	25.50	4.74	0.61
209	13.86	34.51	25.86	4.95	0.77
320	11.85	34.38	26.15	4.99	1.02
420	09.81	34.22	26.39	5.08	1.42
532	07.41	34.07	26.65	4.37	2.02
633	05.64	34.00	26.83	3.42	2.41
846	04.17	34.16	27.12	1.47	2.87
1070	03.34	34.34	27.35	0.74	3.01

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	23.20	34.47	23.50	0.000	1.761
10	23.20	34.47	23.50	0.044	1.717
20	23.14	34.47	23.51	0.088	1.673
30	22.22	34.46	23.77	0.131	1.630
50	20.70	34.58	24.28	0.209	1.552
75	18.38	34.72	24.98	0.293	1.468
100	17.28	34.71	25.24	0.365	1.396
150	15.54	34.62	25.58	0.495	1.266
200	14.04	34.52	25.83	0.613	1.148
250	13.10	34.46	25.97	0.721	1.040
300	12.22	34.41	26.11	0.824	0.937
400	10.23	34.25	26.35	1.012	0.749
500	08.14	34.10	26.57	1.178	0.583
600	06.15	34.01	26.77	1.324	0.437
700	05.08	34.05	26.94	1.453	0.308
800	04.43	34.12	27.06	1.567	0.194
1000	03.48	34.30	27.30	1.761	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 29

M/V *Charles H. Gilbert*: Cruise 17, 34°30'N., 179°52'E., October 17, 1954. Messenger time: 1426 GCT. Weather: 02, cloud coverage 3. Wind: 120°, 18 kt. Sea: 1-3 ft. Wire angle: 33°. BT slide: 128

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	22.06	34.22	23.63	4.97	0.13
16	22.04	34.29	23.69	5.08	0.22
33	19.88	34.34	24.31	5.91	0.18
50	15.84	34.25	25.22	6.74	0.27
83	13.53	34.45	25.88	5.31	0.82
131	12.49	34.34	26.00	5.19	0.95
193	11.64	34.34	26.16	5.03	1.06
294	10.16	34.16	26.29	5.22	1.17
387	08.70	34.11	26.49	4.91	1.46
489	06.98	33.95	26.62	4.25	2.05
584	05.54	34.00	26.84	3.21	2.61
788	04.19	34.11	27.08	1.48	2.77
1003	03.46	34.31	27.31	0.74	3.30

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	22.06	34.22	23.63	0.000	1.577
10	22.05	34.26	23.66	0.043	1.534
20	22.03	34.31	23.71	0.085	1.492
30	22.00	34.32	23.72	0.127	1.450
50	15.84	34.25	25.23	0.196	1.381
75	13.88	34.43	25.79	0.259	1.318
100	13.10	34.41	25.94	0.313	1.264
150	12.23	34.34	26.05	0.416	1.161
200	11.57	34.33	26.17	0.514	1.063
250	10.82	34.24	26.24	0.607	0.970
300	10.04	34.16	26.31	0.698	0.879
400	08.48	34.08	26.50	0.868	0.709
500	06.78	33.95	26.64	1.022	0.555
600	05.38	34.01	26.87	1.159	0.418
700	04.62	34.06	27.00	1.279	0.298
800	04.13	34.13	27.10	1.388	0.189
1000	03.45	34.31	27.31	1.577	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 30

M/V Charles H. Gilbert: Cruise 17, 36°02'N., 179°58'E., October 18, 1954. Messenger time: 0319 GCT. Weather: 01, cloud coverage 8. Wind: 190°, 22 kt. Sea: 3-5 ft. Wire angle: 36°. BT slide: 131

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	20.54	34.20	24.03	5.15	0.25
19	20.51	34.29	24.10	5.12	0.24
35	20.48	34.22	24.06	5.16	0.18
52	19.51	34.42	24.47	5.46	0.26
96	15.65	34.60	25.54	5.16	0.54
143	14.18	34.43	25.73	4.96	0.79
200	13.29	34.45	25.93	4.88	0.86
305	11.74	34.27	26.09	5.05	1.06
404	09.84	34.23	26.40	4.99	1.31
511	07.78	34.00	26.54	4.48	1.88
611	06.05	34.00	26.78	3.81	2.25
828	04.32	34.07	27.03	1.63	2.96
1053	03.49	34.31	27.31	0.87	3.02

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	20.54	34.20	24.03	0.000	1.725
10	20.53	34.25	24.07	0.039	1.686
20	20.51	34.29	24.11	0.077	1.648
30	20.49	34.24	24.07	0.116	1.609
50	19.85	34.37	24.34	0.190	1.535
75	16.80	34.64	25.30	0.269	1.456
100	15.50	34.59	25.56	0.334	1.391
150	14.05	34.43	25.76	0.452	1.273
200	13.29	34.45	25.93	0.563	1.162
250	12.59	34.36	26.00	0.669	1.056
300	11.81	34.28	26.09	0.771	0.954
400	09.94	34.24	26.39	0.958	0.767
500	08.01	34.02	26.52	1.124	0.601
600	06.21	34.00	26.76	1.273	0.452
700	05.19	34.02	26.90	1.404	0.321
800	04.47	34.06	27.01	1.522	0.203
1000	03.58	34.26	27.26	1.725	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 31

M/V Charles H. Gilbert: Cruise 17, 39°28'N., 179°38'E., October 20, 1954. Messenger time: 2037 GCT. Weather: 02, cloud coverage 7. Wind: 140°, 12 kt. Sea: 1-3 ft. Wire angle: 16°. BT slide: 140

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	15.24	34.07	25.22	5.76	0.32
20	15.24	33.95	25.13	5.87	0.29
41	15.04	34.00	25.22	5.81	0.32
61	13.21	34.33	25.85	5.45	0.77
91	11.76	34.33	26.13	5.46	0.93
147	10.44	34.25	26.31	5.52	1.18
233	08.60	34.11	26.50	5.59	1.27
355	06.68	34.02	26.71	4.62	1.82
467	05.38	33.98	26.84	3.48	2.35
587	04.44	34.07	27.02	2.30	2.87
700	04.08	34.16	27.13	1.52	2.95
929	03.50	34.31	27.31	0.84	3.27
PT	-	-	-	-	-

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D\,1000 - \Delta D$ (dyn. m)
00	15.24	34.07	25.22	0.000	1.337
10	15.24	34.01	25.18	0.028	1.309
20	15.24	33.95	25.13	0.056	1.281
30	15.20	33.96	25.15	0.084	1.253
50	14.87	34.02	25.26	0.140	1.197
75	12.38	34.36	26.04	0.199	1.138
100	11.53	34.31	26.16	0.248	1.089
150	10.38	34.24	26.31	0.339	0.998
200	09.22	34.16	26.45	0.423	0.914
250	08.35	34.10	26.54	0.503	0.834
300	07.53	34.06	26.63	0.578	0.759
400	06.16	33.99	26.76	0.719	0.618
500	05.02	34.00	26.90	0.848	0.489
600	04.39	34.08	27.04	0.963	0.374
700	04.08	34.16	27.13	1.067	0.270
800	03.82	34.24	27.22	1.164	0.173
1000	03.51	34.36	27.35	1.337	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 32

M/V *Charles H. Gilbert*: Cruise 17, 45°00'N., 179°27'E., October 23, 1954. Messenger time: 2137 GCT. Weather: 02, cloud coverage 7. Wind: 250°, 25 kt. Sea: 3-5 ft. Wire angle: 51°. BT slide: 151

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	09.56	33.42	25.81	6.42	1.16
17	09.56	33.48	25.85	6.48	1.22
35	09.56	33.51	25.88	6.45	1.15
43	09.57	33.42	25.81	6.43	1.17
63	09.55	33.35	25.76	6.46	1.21
87	07.86	33.69	26.29	6.43	1.33
130	07.38	33.78	26.42	6.40	1.35
198	06.53	33.80	26.56	6.40	1.43
259	06.21	33.84	26.63	5.48	1.68
332	05.38	33.86	26.75	4.55	2.06
408	04.79	33.89	26.84	3.26	2.43
590	04.10	34.09	27.08	1.66	2.72
792	03.56	34.22	27.23	0.96	2.90

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	09.56	33.42	-	-	-
10	09.56	33.44	-	-	-
20	09.56	33.49	-	-	-
30	09.56	33.50	-	-	-
50	09.56	33.38	-	-	-
75	09.48	33.35	-	-	-
100	07.62	33.75	-	-	-
150	07.12	33.79	-	-	-
200	06.49	33.81	-	-	-
250	06.25	33.84	-	-	-
300	05.72	33.85	-	-	-
400	04.81	33.88	-	-	-
500	04.40	33.97	-	-	-
600	04.05	34.10	-	-	-
700	03.79	34.16	-	-	-
800	03.54	34.23	-	-	-

Table 1.--Oceanographic station data (cont'd)

STATION 33

M/V Charles H. Gilbert: Cruise 17, 44°57'N., 175°47'E., October 24, 1954. Messenger time: 2326 GCT. Weather: 02, cloud coverage 6. Wind: 340°, 14 kt. Sea: 3-5 ft. Wire angle: 06°. BT slide: 156

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	08.54	33.22	25.82	6.62	1.38
30	08.52	33.28	25.87	6.61	1.37
66	07.76	33.53	26.18	6.46	1.29
98	06.76	33.69	26.44	6.43	1.31
141	05.84	33.71	26.57	6.36	1.43
183	05.54	33.77	26.66	6.10	1.56
246	04.98	33.84	26.78	4.66	1.96
373	04.20	33.93	26.94	2.75	2.55
489	03.92	34.04	27.05	1.86	2.73
613	03.57	34.16	27.18	1.09	2.76
726	03.38	34.25	27.27	0.87	2.89
961	03.02	34.36	27.39	0.80	2.86
PT	-	-	-	-	-

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	08.54	33.22	25.82	0.000	1.132
10	08.54	33.23	25.83	0.022	1.110
20	08.53	33.25	25.84	0.044	1.088
30	08.52	33.28	25.87	0.065	1.067
50	08.52	33.40	25.96	0.107	1.025
75	07.39	33.59	26.28	0.155	0.977
100	06.66	33.69	26.46	0.197	0.935
150	05.79	33.72	26.59	0.274	0.858
200	05.39	33.80	26.70	0.345	0.787
250	04.92	33.85	26.80	0.412	0.720
300	04.49	33.89	26.87	0.474	0.658
400	04.12	33.96	26.97	0.591	0.541
500	03.86	34.07	27.08	0.699	0.433
600	03.60	34.14	27.16	0.799	0.333
700	03.40	34.23	27.26	0.890	0.242
800	03.24	34.28	27.31	0.975	0.157
1000	03.00	34.38	27.41	1.132	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 34

M/V *Charles H. Gilbert*: Cruise 17, 35°45'N., 171°32'E., October 28, 1954. Messenger time: 1910 GCT. Weather: 02, cloud coverage 8. Wind: 060°, 07 kt. Sea: 1-3 ft. Wire angle: 30°. BT slide: 175

OBSERVED

DEPTH * (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	NG	34.38	-	5.15	0.27
21	20.28	34.49	24.32	5.21	0.30
46	20.26	34.49	24.33	5.15	0.20
74	20.10	34.49	24.37	4.92	0.33
106	18.23	34.78	25.06	4.08	0.70
145	16.72	34.79	25.44	4.69	0.63
180	15.94	34.74	25.58	4.64	0.62
251	14.00	34.58	25.88	4.43	0.89
312	12.32	34.49	26.15	4.78	1.03
381	11.76	34.45	26.23	4.48	1.17
**	-	-	-	-	-
**	-	-	-	-	-
**	-	-	-	-	-

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	20.30	34.38	-	-	-
10	20.29	34.44	-	-	-
20	20.28	34.49	-	-	-
30	20.27	34.49	-	-	-
50	20.26	34.49	-	-	-
75	20.09	34.49	-	-	-
100	19.82	34.51	-	-	-
150	16.60	34.79	-	-	-
200	15.47	34.70	-	-	-
250	14.10	34.59	-	-	-
300	12.54	34.50	-	-	-
400	11.65	34.45	-	-	-

* All depths somewhat questionable.

** Last three bottles apparently fouled a ridge.

Table 1.--Oceanographic station data (cont'd)

STATION 35

M/V *Charles H. Gilbert*: Cruise 17, 31°23'N., 172°01'E., October 29, 1954. Messenger time: 0549 GCT. Weather: 02, cloud coverage 6. Wind: 170°, 18 kt. Sea: 5-8 ft. Wire angle: 27°. BT slide: 184

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	23.12	34.69	23.69	4.90	0.29
23	22.96	34.76	23.78	4.88	0.28
51	22.94	34.74	23.77	4.88	0.23
69	21.10	34.74	24.29	5.31	0.25
97	18.38	34.76	25.01	5.21	0.33
149	16.73	34.74	25.40	4.88	0.56
204	16.10	NS	-	4.70	0.63
308	14.70	NS	-	4.55	0.74
414	12.66	34.45	26.05	4.78	1.05
521	10.38	34.34	26.39	4.65	1.40
628	07.31	33.96	26.58	4.23	1.98
846	NG	34.22	-	1.71	3.64
1064	03.52	34.36	27.35	0.87	3.46

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D\,1000 - \Delta D$ (dyn. m)
00	23.12	34.69	23.68	0.000	1.967
10	23.00	34.74	23.76	0.042	1.925
20	22.97	34.76	23.78	0.083	1.884
30	22.95	34.75	23.78	0.125	1.842
50	22.94	34.74	23.77	0.208	1.759
75	20.15	34.75	24.55	0.302	1.665
100	18.18	34.76	25.06	0.382	1.585
150	16.72	34.74	25.40	0.521	1.446
200	16.17	34.70	25.50	0.651	1.316
250	15.55	34.66	25.61	0.776	1.191
300	14.81	34.60	25.72	0.897	1.070
400	12.95	34.46	26.00	1.121	0.846
500	10.99	34.36	26.30	1.319	0.648
600	07.99	34.02	26.53	1.492	0.475
700	06.20	34.02	26.78	1.641	0.326
800	05.15	34.17	27.02	1.767	0.200
1000	03.74	34.33	27.30	1.967	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 36

M/V Charles H. Gilbert: Cruise 17, 30°59'N., 173°52'E., October 30, 1954. Messenger time: 1852 GCT. Weather: 60, cloud coverage 8. Wind: 200°, 14 kt. Sea: 3-5 ft. Wire angle: 29°. BT slide: 187

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	24.52	34.94	23.46	4.65	0.04
26	24.54	35.35	23.76	4.71	0.04
52	24.46	35.35	23.79	4.70	0.12
66	20.38	34.97	24.66	5.42	0.11
83	18.47	34.83	25.04	5.27	0.19
137	16.58	34.70	25.40	4.89	0.40
195	15.82	34.65	25.54	4.78	0.56
293	14.02	34.52	25.83	4.63	0.84
391	12.14	34.40	26.12	4.70	1.07
490	10.24	34.23	26.33	4.42	1.35
590	07.81	34.13	26.64	4.01	1.87
798	04.82	34.13	27.03	1.98	2.90
1008	03.80	34.31	27.28	0.86	3.36

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	24.52	34.94	23.46	0.000	1.900
10	24.53	35.06	23.55	0.044	1.856
20	24.54	35.26	23.70	0.087	1.813
30	24.54	35.35	23.77	0.129	1.771
50	24.47	35.35	23.79	0.212	1.688
75	19.12	34.87	24.91	0.302	1.598
100	17.56	34.76	25.21	0.375	1.525
150	16.39	34.68	25.43	0.510	1.390
200	15.78	34.65	25.55	0.638	1.262
250	14.92	34.59	25.69	0.760	1.140
300	13.94	34.51	25.84	0.876	1.024
400	11.98	34.38	26.13	1.088	0.812
500	10.02	34.22	26.36	1.276	0.624
600	07.61	34.12	26.66	1.439	0.461
700	06.01	34.09	26.85	1.578	0.322
800	04.81	34.13	27.03	1.699	0.201
1000	03.81	34.31	27.28	1.900	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 37

M/V Charles H. Gilbert: Cruise 17, 30°15'N., 175°36'E., October 31, 1954. Messenger time: 0756 GCT. Weather: 02, cloud coverage not recorded. Wind: 190°, 14 kt. Sea: 1-3 ft. Wire angle: 27°. BT slide: 190

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	24.75	35.37	23.72	4.70	0.23
22	24.72	35.35	23.71	4.71	0.22
49	24.63	35.37	23.75	4.67	0.17
63	24.17	35.30	23.84	4.85	0.29
99	17.91	34.83	25.18	5.60	0.28
126	16.54	34.72	25.43	5.23	0.42
198	15.12	34.61	25.66	4.80	0.70
296	13.61	34.49	25.89	4.69	0.93
396	11.63	34.33	26.15	4.61	1.23
495	09.77	34.20	26.39	4.41	1.66
595	07.73	34.11	26.63	4.05	1.88
796	04.82	34.09	27.00	2.09	3.28
976	03.71	34.25	27.24	0.78	3.70

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	24.75	35.37	23.72	0.000	1.885
10	24.74	35.36	23.71	0.042	1.843
20	24.72	35.35	23.71	0.084	1.801
30	24.70	35.36	23.72	0.126	1.759
50	24.62	35.37	23.76	0.210	1.675
75	19.50	34.94	24.87	0.301	1.584
100	17.80	34.82	25.20	0.375	1.510
150	15.86	34.67	25.54	0.507	1.378
200	15.09	34.61	25.67	0.629	1.256
250	14.40	34.55	25.77	0.747	1.138
300	13.55	34.48	25.90	0.859	1.026
400	11.58	34.32	26.16	1.067	0.818
500	09.64	34.20	26.41	1.251	0.634
600	07.62	34.10	26.64	1.412	0.473
700	05.99	34.05	26.83	1.553	0.332
800	04.80	34.09	27.00	1.677	0.208
1000	03.71	34.24	27.23	1.885	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 38

M/V Charles H. Gilbert: Cruise 17, 29°39'N., 177°19'E., October 31, 1954. Messenger time: 2041 GCT. Weather: 02, cloud coverage 1. Wind: 210°, 18 kt. Sea: 3-5 ft. Wire angle: 25°. BT slide: 193

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	25.63	35.59	23.61	4.59	0.12
30	25.63	35.55	23.58	4.61	0.15
60	25.64	35.57	23.59	4.57	0.09
70	22.98	35.32	24.20	5.23	0.14
100	20.32	35.17	24.83	4.84	0.17
160	17.24	34.79	25.31	4.91	0.42
220	16.13	34.69	25.50	4.91	0.59
330	14.47	34.56	25.77	4.57	0.81
440	12.12	34.38	26.11	4.68	1.10
550	10.00	34.23	26.37	4.38	1.36
660	07.35	NG	-	NG	NG
880	04.83	34.11	27.01	1.67	3.46
1163	03.37	34.40	27.39	0.59	3.64

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	25.63	35.59	23.61	0.000	2.040
10	25.63	35.58	23.61	0.043	1.997
20	25.63	35.57	23.60	0.086	1.954
30	25.63	35.55	23.58	0.129	1.911
50	25.64	35.57	23.60	0.216	1.824
75	22.28	35.26	24.36	0.315	1.725
100	20.32	35.17	24.83	0.400	1.640
150	17.60	34.82	25.25	0.548	1.492
200	16.42	34.72	25.45	0.683	1.357
250	15.70	34.66	25.57	0.810	1.230
300	15.00	34.60	25.68	0.932	1.108
400	12.98	34.45	25.99	1.159	0.881
500	10.98	34.30	26.25	1.360	0.680
600	08.62	34.17	26.55	1.534	0.506
700	06.67	34.08	26.76	1.684	0.356
800	05.52	34.07	26.90	1.817	0.223
1000	04.04	34.22	27.18	2.040	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 39

M/V Charles H. Gilbert: Cruise 17, 28°55'N., 178°50'E., November 1, 1954. Messenger time: 0832 GCT. Weather: 02, cloud coverage 1. Wind: 220°, 13 kt. Sea: 1-3 ft. Wire angle: 15°. BT slide: 196

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	24.12	35.17	23.76	4.83	0.16
26	24.12	35.16	23.75	4.82	0.20
44	21.28	34.90	24.36	5.54	0.18
62	19.76	34.88	24.75	5.64	0.16
92	17.89	34.85	25.20	5.38	0.33
149	16.29	34.69	25.46	4.95	0.48
225	15.29	34.65	25.66	4.81	0.62
337	13.34	34.51	25.96	4.95	0.83
449	11.52	34.33	26.18	4.81	1.16
561	09.15	34.18	26.47	4.21	1.67
673	06.80	34.25	26.88	3.94	1.77
895	04.83	34.16	27.04	1.35	3.43
1076	03.58	34.36	27.34	0.68	3.54

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	24.12	35.17	23.76	0.000	1.894
10	24.12	35.17	23.76	0.042	1.852
20	24.12	35.16	23.75	0.083	1.811
30	24.11	35.16	23.75	0.125	1.769
50	20.62	34.88	24.52	0.201	1.693
75	18.85	34.88	24.99	0.281	1.613
100	17.62	34.82	25.25	0.354	1.540
150	16.30	34.69	25.46	0.487	1.407
200	15.65	34.66	25.58	0.613	1.281
250	14.90	34.63	25.73	0.734	1.160
300	14.00	34.56	25.87	0.848	1.046
400	12.32	34.41	26.09	1.061	0.833
500	10.53	34.26	26.30	1.254	0.640
600	08.22	34.19	26.63	1.422	0.472
700	06.45	34.24	26.92	1.561	0.333
800	05.59	34.19	26.99	1.682	0.212
1000	04.01	34.27	27.23	1.894	0.000

Table 1.--Oceanographic station data (cont'd)

STATION 40

M/V Charles H. Gilbert: Cruise 17, 28°11'N., 179°43'W., November 1, 1954. Messenger time: 1928 GCT. Weather: 02, cloud coverage 1. Wind: 260°, 10 kt. Sea: <1 ft. Wire angle: 15°. BT slide: 199

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	24.19	35.14	23.71	4.74	0.21
20	24.19	35.14	23.71	4.75	0.14
35	24.19	35.16	23.73	4.77	0.17
50	20.51	34.84	24.52	5.67	0.19
76	17.58	34.72	25.18	5.59	0.21
132	16.08	34.65	25.48	4.91	0.54
224	15.09	34.52	25.60	4.89	0.72
337	13.38	34.43	25.89	4.75	0.97
449	11.21	34.29	26.20	4.76	1.29
561	08.77	34.13	26.49	4.39	1.83
671	06.30	34.27	26.96	4.06	1.52 P
892	04.16	34.22	27.17	1.00	3.56
1112	03.40	34.47	27.45	0.61	3.55

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	24.19	35.14	23.71	0.000	1.854
10	24.19	35.14	23.71	0.042	1.812
20	24.19	35.14	23.71	0.084	1.770
30	24.19	35.15	23.72	0.126	1.728
50	20.51	34.84	24.52	0.202	1.652
75	17.60	34.72	25.17	0.281	1.573
100	16.75	34.68	25.35	0.349	1.505
150	15.87	34.62	25.50	0.479	1.375
200	15.36	34.54	25.56	0.605	1.249
250	14.78	34.50	25.65	0.728	1.126
300	14.02	34.47	25.79	0.846	1.008
400	12.19	34.33	26.05	1.064	0.790
500	10.15	34.22	26.34	1.257	0.597
600	07.85	34.19	26.68	1.420	0.434
700	05.86	34.25	27.00	1.552	0.302
800	04.76	34.23	27.11	1.662	0.192
1000	03.70	34.30	27.28	1.854	0.000

Table 2.--Summary of observations at bathythermograph lowerings, *Charles H. Gilbert* cruise 17, September 17 to November 7, 1954 (For coded values see H. O. Pub. 606-C)

Ser. No.	Time, GCT	Date, 1954	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
1	2345	9/18	22°30'N	160°00'W	79.1	100	24	79.9	76.2	1015.2	01	6	5	9	3
2	0405	9/19	22°29'N	160°02'W	79.4	070	16	78.2	72.9	1011.2	02	9	4	9	4
3	0800	9/19	23°03'N	159°59'W	79.2	050	24	77.3	71.4	1015.2	02	4	8	X	4
4	1215	9/19	23°35'N	159°58'W	77.9	070	16	78.2	73.8	1014.9	02	4	1	9	3
5	1630	9/19	24°13'N	159°54'W	77.8	090	16	75.9	72.8	1015.2	02	4, 6	2	9	2
6	1950	9/19	24°12'N	159°59'W	78.0	090	16	77.2	73.5	1012.5	02	4, 6	3	9	2
7	0000	9/20	24°44'N	159°56'W	78.4	070	16	78.2	71.7	1013.5	02	4	2	9	2
8	0410	9/20	25°13'N	159°53'W	77.2	055	10	76.3	72.5	1014.2	02	9	1	9	2
9	0625	9/20	25°34'N	159°53'W	76.8	040	17	76.9	73.0	1015.2	02	9	1	9	2
10	0840	9/20	25°34'N	159°55'W	76.9	035	08	75.8	72.2	1015.6	02	X	X	9	2
11	1255	9/20	26°07'N	159°57'W	77.2	070	09	75.2	72.3	1014.6	02	9	1	9	2
12	1645	9/20	26°40'N	160°00'W	77.0	060	10	75.9	69.9	1015.2	02	9	3	8	2
13	1905	9/20	27°01'N	159°59'W	77.8	045	10	77.8	75.0	1015.9	02	8	2	9	2
14	2120	9/20	27°00'N	160°01'W	78.2	045	10	80.5	75.0	1016.6	02	8, 6	5	9	2
15	0115	9/21	27°32'N	160°00'W	78.9	050	13	77.7	71.8	1015.2	02	8, 6	3	9	2
16	0515	9/21	28°00'N	160°00'W	77.3	040	10	76.2	73.0	1014.2	02	1, 8, 9	3	X	2
17	0845	9/21	28°29'N	160°00'W	76.8	095	10	75.8	72.8	1016.6	02	X	X	8	2
18	1045	9/21	28°28'N	159°59'W	76.6	calm	calm	75.2	72.0	1017.6	02	X	X	8	1
19	1435	9/21	29°07'N	159°54'W	76.4	030	05	73.7	67.7	1016.9	02	8	1	X	1
20	1850	9/21	29°51'N	159°49'W	75.7	040	07	74.6	72.8	1018.3	02	9, 2	2	9	1
21	1955	9/21	30°03'N	159°49'W	76.0	calm	calm	78.9	72.8	1015.9	02	9	1	9	1
22	2210	9/21	30°03'N	159°46'W	77.1	000	01	78.2	71.9	1018.6	02	8	2	9	1
23	0215	9/22	30°35'N	159°47'W	77.2	000	12	78.9	72.6	1016.6	02	8	1	9	1
24	0600	9/22	31°08'N	159°50'W	76.8	000	12	77.4	72.8	1018.3	02	8	2	9	1
25	0855	9/22	31°29'N	159°50'W	75.6	calm	calm	74.5	69.0	1018.3	02	X	X	9	1
26	1115	9/22	31°31'N	159°50'W	75.7	calm	calm	74.0	69.7	1018.3	02	0	0	9	1
27	1510	9/22	32°04'N	159°52'W	75.2	calm	calm	73.6	70.1	1018.0	23	X	X	6	1
28	1915	9/22	32°40'N	159°54'W	77.2	300	06	74.0	71.2	1018.0	01	4, 8	1	9	1
29	2045	9/22	32°57'N	159°55'W	76.7	300	06	74.6	72.3	1018.0	02	4, 8	1	9	1
30	2245	9/22	32°58'N	159°55'W	75.0	255	09	75.0	73.5	1016.9	03	8, 4	6	9	1

Table 2.--Summary of observations at bathythermograph lowerings, *Charles H. Gilbert* cruise 17, September 17 to November 7, 1954 (For coded values see H. O. Pub. 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1954	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Baro-meter, mb.	Wea-ther	Clouds		Visi-bili-ty	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
31	0345	9/23	33°33'N	160°02'W	76.0	270	12	76.5	74.4	1015.6	02	8, 7	7	8	2
32	0615	9/23	34°06'N	160°07'W	75.0	315	07	75.2	72.1	1015.6	02	1, 4, 8	3	9	3
33	0923	9/23	34°29'N	160°08'W	74.1	235	18	74.5	74.0	1013.2	02	X	0	9	3
34	1130	9/23	34°30'N	160°09'W	73.9	280	20	73.9	71.0	1015.2	02	0	0	9	3
35	1530	9/23	35°03'N	160°05'W	74.5	230	18	73.7	70.0	1013.5	02	3, 6, 8	6	6	3
36	1840	9/23	35°34'N	160°02'W	74.1	250	21	75.3	73.6	1013.2	02	8, 3	4	9	4
37	2225	9/23	36°08'N	159°57'W	74.3	260	30	75.3	74.0	1011.9	02	8, 2	7	6	5
38	0400	9/24	36°42'N	159°57'W	74.0	235	30	75.3	75.0	1010.5	02	8, 5	6	6	5
39	0720	9/24	37°09'N	159°59'W	73.4	270	22	74.0	71.8	1008.5	02	X	X	X	5
40	1120	9/24	37°44'N	160°02'W	72.0	300	19	69.5	68.5	1013.2	02	X	9	X	4
41	1435	9/24	38°17'N	160°04'W	70.9	340	14	68.2	63.5	1014.2	02	8	7	X	3
42	1830	9/24	38°54'N	160°06'W	71.5	000	11	68.3	63.8	1015.2	02	4, 5	6	8	3
43	2300	9/24	38°57'N	160°05'W	71.4	065	10	69.1	63.8	1018.0	60	7, 5, 4	9	8	2
44	0400	9/25	39°25'N	160°08'W	70.5	065	24	63.9	61.8	1016.9	61	7	9	7	3
45	0730	9/25	39°51'N	160°11'W	70.1	045	23	65.5	63.3	1018.3	61	X	X	X	3
46	1115	9/25	40°19'N	160°14'W	70.0	040	34	63.3	62.8	1016.9	65	X	9	4	5
47	0045	9/26	41°07'N	160°42'W	67.5	030	35	61.0	59.8	1015.9	60	0	9	4	6
48	1645	9/26	42°02'N	160°17'W	65.1	330	26	62.0	60.2	1014.6	02	0	9	0	5
49	2310	9/26	42°07'N	159°59'W	65.6	345	15	66.1	61.3	1012.5	02	6, 8	4	8	2
50	0510	9/27	42°38'N	160°01'W	64.8	350	10	59.3	58.6	1011.2	50	6, 9	7	7	2
51	0845	9/27	43°09'N	160°01'W	65.3	000	04	62.0	58.5	1011.9	02	8	1	8	2
52	1210	9/27	43°39'N	160°01'W	66.0	150	04	64.8	59.6	1011.5	02	X	0	X	2
53	1425	9/27	43°42'N	160°00'W	65.9	105	14	62.5	58.1	1013.5	02	X	0	8	2
54	1900	9/27	43°21'N	160°00'W	61.5	125	20	63.6	60.8	1010.8	02	1, 2, 3	5	8	2
55	2230	9/27	43°54'N	160°00'W	62.5	135	27	64.8	63.9	1008.5	60	0	9	4	3
56	2300	9/27	43°51'N	160°00'W	62.8	135	27	65.4	64.9	XXXX	XX	X	X	X	X
57	2350	9/27	43°47'N	160°00'W	66.1	135	27	68.2	66.7	1007.8	60	0	8	4	3
58	1915	9/30	44°06'N	160°05'W	61.9	000	XX	64.0	63.5	994.9	03	0, 1, 2	3	8	6
59	2035	9/30	44°36'N	160°12'W	62.0	110	22	64.0	62.3	995.3	15	0, 1, 2, 9	5	7	4
60	2305	9/30	44°58'N	160°12'W	61.0	115	20	63.8	62.0	995.3	02	7, 0	9	7	4

Table 2.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 17, September 17 to November 7, 1954 (For coded values see H. O. Pub. 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1954	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Baro-meter, mb.	Wea-ther	Clouds		Visi-bili-ty	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
61	0230	10/1	44°59'N	160°50'W	61.4	230	05	63.9	62.2	994.2	02	4, 8, 6	6	7	5
62	0620	10/1	45°00'N	161°30'W	60.4	260	22	60.1	57.2	995.6	26	X	X	4	5
63	0930	10/1	45°01'N	162°09'W	59.9	260	22	59.0	55.2	998.3	01	6, 8	4	X	4
64	1300	10/1	45°02'N	162°59'W	60.4	205	18	60.4	57.3	998.3	02	X	X	X	5
65	1235	10/1	45°03'N	163°43'W	59.9	180	18	58.2	57.4	996.6	50	0, 8	8	5	4
66	0035	10/2	45°04'N	164°11'W	59.5	280	22	57.2	53.5	993.6	01	2, 5, 8	2	8	3
67	0400	10/2	45°04'N	164°40'W	58.9	210	26	56.0	53.0	995.3	52	6, 9	5	7	4
68	0730	10/2	45°05'N	165°08'W	58.7	250	20	56.6	54.8	997.3	25	8	3	X	4
69	1120	10/2	45°05'N	165°41'W	59.1	230	24	55.7	52.4	996.3	01	8, 2	2	8	4
70	1505	10/2	45°05'N	166°17'W	57.0	210	24	52.1	51.5	996.6	52	8, 9	5	X	4
71	2335	10/2	45°03'N	166°55'W	57.5	235	30	55.8	51.8	1000.0	02	8	3	8	6
72	0415	10/3	44°50'N	167°27'W	56.3	230	32	55.0	51.3	1002.7	02	0, 8	7	7	5
73	1110	10/3	44°38'N	167°56'W	56.5	230	29	54.8	52.7	1003.4	02	X	8	7	5
74	1715	10/3	44°26'N	168°25'W	56.0	210	28	55.0	53.2	1005.1	15	6, 9	8	7	4
75	2100	10/3	44°17'N	168°48'W	56.1	212	28	56.2	54.3	1007.5	02	0, 9	8	7	4
76	0100	10/4	44°05'N	169°20'W	56.2	245	18	59.0	55.8	1007.1	02	1, 6, 8	6	7	5
77	0430	10/4	43°48'N	169°43'W	57.0	330	03	56.9	55.0	1005.4	02	8, 9	8	7	3
78	1040	10/4	43°15'N	169°47'W	57.0	210	07	58.2	56.1	1009.1	02	0	8	7	1
79	1400	10/4	42°44'N	169°50'W	58.7	160	10	58.3	57.2	1010.8	02	X	8	X	2
80	1750	10/4	42°14'N	169°53'W	59.1	140	13	60.2	59.6	1012.5	50	0	8	6	2
81	2330	10/4	41°48'N	169°51'W	59.8	180	22	61.7	61.9	1014.6	47	X	X	0	2
82	0300	10/5	41°24'N	169°49'W	61.5	185	19	63.9	63.2	1013.9	01	X	0	9	3
83	0645	10/5	41°00'N	169°47'W	61.5	210	22	63.5	62.5	1013.2	02	X	X	9	3
84	1235	10/5	40°37'N	169°47'W	61.7	160	25	64.5	63.6	1011.2	02	X	6	X	4
85	1815	10/5	40°10'N	169°45'W	65.1	210	30	66.0	65.0	1009.5	02	0	8	9	5
86	2300	10/5	39°42'N	169°43'W	64.8	200	22	67.8	66.0	1011.2	02	0, 2	6	9	4
87	0300	10/6	39°13'N	169°49'W	65.1	200	13	67.6	66.1	1012.2	02	4	1	9	4
88	0730	10/6	38°41'N	169°57'W	64.9	200	05	66.0	65.0	1013.5	02	0	0	9	2
89	1345	10/6	38°10'N	170°01'W	64.9	190	05	64.8	64.5	1013.5	28	X	X	3	1
90	1715	10/6	37°42'N	170°04'W	64.6	230	03	64.3	64.3	1014.2	44	X	8	0	1

Table 2.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 17, September 17 to November 7, 1954 (For coded values see H. O. Pub. 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1954	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
91	0445	10/7	37°07'N	170°05'W	68.9	000	00	68.5	68.0	1012.5	28	X	9	3	1
92	1030	10/7	36°34'N	170°05'W	68.0	180	26	71.7	70.0	1012.5	00	X	X	X	4
93	1400	10/7	36°06'N	170°06'W	70.5	160	26	72.0	70.5	1012.9	00	X	X	X	4
94	1910	10/7	35°29'N	170°07'W	70.0	210	27	72.2	70.0	1014.9	02	8	5	X	4
95	2235	10/7	35°00'N	170°07'W	70.3	210	25	73.6	71.0	1015.2	03	8, 6	7	8	4
96	0230	10/8	34°34'N	170°09'W	72.1	210	21	74.5	72.1	1015.2	02	8, 6	6	9	4
97	0550	10/8	34°07'N	170°12'W	72.2	190	19	74.0	72.0	1016.3	02	2, 6	3	9	3
98	0750	10/8	34°04'N	170°12'W	72.4	190	18	74.3	72.0	1017.6	02	2, 6	3	9	3
99	1130	10/8	33°35'N	170°13'W	72.0	195	19	73.8	72.0	1018.6	03	7, 2	6	9	3
100	1510	10/8	33°06'N	170°15'W	72.9	190	15	74.8	72.4	1019.0	02	X	0	9	2
101	1920	10/8	32°29'N	170°18'W	73.8	220	08	75.8	73.3	1022.4	02	8	1	9	1
102	0100	10/9	32°02'N	170°15'W	74.9	160	11	77.0	73.9	1022.0	02	8	1	9	2
103	0400	10/9	31°36'N	170°12'W	75.0	180	14	76.1	73.9	1024.0	02	X	0	9	2
104	1100	10/9	30°45'N	170°10'W	75.2	150	15	76.4	74.0	1025.4	01	4	1	9	2
105	1415	10/9	30°17'N	170°10'W	76.7	180	16	77.0	74.2	1024.4	02	2, 8	2	9	2
106	1615	10/9	30°00'N	170°10'W	76.4	090	08	77.0	74.0	1025.1	02	8	1	9	1
107	2205	10/9	29°55'N	170°51'W	76.8	130	10	81.0	74.6	1027.4	02	8	2	7	2
108	0130	10/10	29°50'N	171°30'W	77.9	220	04	82.4	75.6	1026.1	02	8, 4	2	9	2
109	0515	10/10	29°45'N	172°05'W	77.3	110	12	77.7	73.0	1026.4	02	8, 2	1	9	2
110	1030	10/10	29°36'N	172°38'W	77.0	050	12	78.0	74.1	1028.1	02	8	1	9	2
111	1350	10/10	29°28'N	173°10'W	76.3	150	05	79.2	74.5	1026.4	02	8	3	9	2
112	1745	10/10	29°17'N	173°54'W	76.6	090	12	78.2	72.5	1029.8	02	8	2	9	2
113	2340	10/10	29°04'N	174°34'W	77.0	070	16	80.1	72.5	1025.7	02	8	2	8	3
114	0815	10/15	28°47'N	178°18'W	77.3	090	10	76.0	73.2	1021.0	02	0	6	8	2
115	1050	10/15	28°47'N	178°18'W	77.4	090	08	76.0	72.8	1021.0	02	0	6	8	1
116	1430	10/15	29°03'N	178°45'W	76.7	080	14	76.0	72.8	1020.3	02	0	6	8	1
117	1800	10/15	29°25'N	179°10'W	76.3	060	05	75.5	68.8	1021.3	02	6	1	8	1
118	2120	10/15	29°34'N	179°42'W	77.4	000	00	78.3	73.1	1020.7	02	X	0	8	1
119	0145	10/16	29°51'N	179°45'E	76.9	150	05	81.8	73.3	1019.6	02	8	1	8	1
120	0545	10/16	30°18'N	179°45'E	76.8	000	00	77.9	74.8	1019.3	02	0	7	8	1

Table 2.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 17, September 17 to November 7, 1954 (For coded values see H. O. Pub. 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1954	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Baro-meter, mb.	Wea-ther	Clouds		Visi-bili-ty	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
121	0850	10/16	30°45'N	179°42'E	76.1	000	00	76.9	71.7	1020.0	02	8	3	8	1
122	1345	10/16	31°30'N	179°37'E	74.9	180	04	75.2	72.0	1020.0	02	8	2	8	1
123	1915	10/16	32°08'N	179°40'E	75.0	000	12	72.5	71.0	1021.0	51	1,9	7	7	2
124	2200	10/16	32°29'N	179°47'E	74.6	065	07	75.3	72.0	1020.7	01	8,2	3	8	2
125	0150	10/17	32°59'N	179°58'E	73.8	080	22	75.3	70.5	1020.3	02	8,2	3	8	2
126	0715	10/17	33°30'N	179°53'E	72.2	105	16	71.8	67.7	1022.4	03	5,8	4	8	2
127	1035	10/17	33°59'N	179°49'E	71.0	080	18	70.0	66.0	1022.0	02	5,8	4	X	3
128	1400	10/17	34°30'N	179°52'E	71.3	115	18	70.0	66.8	1021.0	02	8	3	8	2
129	1915	10/17	35°03'N	179°54'E	69.2	160	18	70.0	67.5	1020.0	02	6	8	8	2
130	2250	10/17	35°28'N	179°57'E	69.8	160	15	70.8	69.5	1017.3	02	0,5	8	8	2
131	0250	10/18	36°02'N	179°58'E	68.8	185	22	71.8	69.3	1012.5	01	2,5	8	8	3
132	0815	10/18	36°35'N	179°59'E	65.6	180	33	70.9	68.5	1009.1	02	X	7	X	4
133	2020	10/19	36°33'N	179°32'W	64.7	045	26	60.0	64.7	1026.4	02	8	6	8	5
134	0030	10/20	37°02'N	179°37'W	63.0	060	20	59.8	53.5	1026.4	02	1,8	4	8	4
135	0430	10/20	37°21'N	179°42'W	63.8	060	21	60.0	52.2	1028.8	02	1,8	4	8	4
136	0850	10/20	37°55'N	179°53'W	63.5	065	17	57.8	56.7	1030.1	02	X	X	8	4
137	1145	10/20	38°17'N	180°00'	58.4	070	10	55.7	50.3	1030.5	02	X	9	5	3
138	1300	10/20	38°30'N	179°56'E	58.7	000	10	55.0	48.0	1030.8	01	6	5	5	3
139	1700	10/20	39°04'N	179°46'E	59.7	075	06	55.3	48.7	1030.5	01	6	7	8	2
140	2000	10/20	39°28'N	179°38'E	58.9	135	12	55.7	54.1	1030.5	02	2,5,8	7	8	2
141	0040	10/21	39°45'N	179°38'E	59.1	175	20	58.1	52.3	1029.5	02	2,5,8	2	8	2
142	0320	10/21	40°10'N	179°38'E	58.0	180	24	57.0	52.3	1022.4	02	1,3,4,8	6	8	4
143	0600	10/21	40°35'N	179°38'E	57.2	170	27	59.2	54.4	1020.3	02	5,6	9	8	4
144	0920	10/21	41°12'N	179°38'E	57.5	170	34	58.1	56.2	1012.5	65	X	X	1	5
145	1830	10/22	42°09'N	179°50'E	55.9	310	38	50.8	47.7	1016.6	02	8	2	8	5
146	0000	10/23	42°31'N	179°49'E	53.0	350	22	50.0	45.0	1015.6	03	6,9	9	8	5
147	0600	10/23	43°19'N	179°49'E	51.1	310	10	47.2	42.2	1014.6	02	4,8	9	8	2
148	1120	10/23	43°59'N	179°47'E	49.1	270	08	47.2	46.5	1011.5	02	X	X	8	2
149	1500	10/23	44°31'N	179°46'E	47.3	310	15	46.9	43.8	1009.1	02	X	X	8	2
150	1900	10/23	45°00'N	179°42'E	48.5	250	22	45.5	41.2	1008.5	02	6,4,8	7	8	3

Table 2.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 17, September 17 to November 7, 1954 (For coded values see H. O. Pub. 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1954	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
151	2035	10/23	45°00'N	179°27'E	49.0	250	25	46.0	42.2	1010.2	02	6,9	7	7	3
152	0300	10/24	44°57'N	178°58'E	48.6	030	40	45.8	42.5	1011.5	02	8	6	8	4
153	1040	10/24	45°00'N	177°58'E	48.1	350	24	44.0	41.9	1019.3	02	X	X	8	5
154	1435	10/24	44°56'N	177°11'E	48.2	350	28	45.2	40.5	1019.6	02	X	7	7	4
155	1830	10/24	44°56'N	176°32'E	47.2	030	28	45.6	41.9	1023.4	02	5,8	9	8	4
156	2220	10/24	44°57'N	175°47'E	47.0	340	14	45.9	42.0	1024.0	02	6,4,8	6	8	3
157	0435	10/25	44°58'N	175°02'E	48.9	185	19	48.4	45.1	1021.0	02	6,8	7	8	2
158	0805	10/25	44°58'N	174°25'E	50.3	190	18	48.7	44.3	1015.9	02	X	8	7	3
159	1150	10/25	44°58'N	173°43'E	49.7	145	34	48.0	46.0	1008.5	53	X	9	X	4
160	1620	10/25	45°00'N	172°33'E	48.7	285	25	49.1	47.3	993.9	53	X	X	X	4
160A	1940	10/25	44°59'N	171°46'E	49.9	285	27	49.1	47.3	988.8	02	4,8	2	8	4
161	2045	10/26	42°18'N	172°07'E	52.8	330	19	49.0	44.5	1017.3	02	0	8	7	4
162	0300	10/27	41°36'N	172°14'E	52.2	330	22	52.1	48.0	1016.3	02	0	7	7	4
163	0630	10/27	41°12'N	172°17'E	55.1	300	24	53.0	47.1	1016.3	02	6	8	7	4
164	0935	10/27	40°45'N	172°13'E	59.7	300	32	55.7	50.0	1016.9	02	6	8	7	4
165	1235	10/27	40°18'N	172°09'E	58.9	270	30	55.2	49.8	1017.6	02	X	X	7	4
166	1535	10/27	39°51'N	172°05'E	59.2	285	30	55.0	49.8	1018.3	02	X	X	7	4
167	1835	10/27	39°23'N	172°01'E	62.6	300	27	58.4	51.8	1019.0	02	4,8	9	8	4
168	2130	10/27	38°56'N	171°57'E	59.8	290	20	56.2	53.2	1020.7	02	4,8	8	8	4
169	0030	10/28	38°27'N	171°53'E	63.6	300	28	59.0	53.9	1020.3	01	4,8	4	8	4
170	0340	10/28	38°01'N	171°50'E	63.4	305	16	60.0	55.0	1020.3	02	8	4	8	5
171	0630	10/28	37°34'N	171°46'E	64.0	310	22	60.0	54.4	1020.3	02	6	8	8	4
172	0930	10/28	37°08'N	171°42'E	64.6	310	20	60.3	55.4	1021.7	02	X	8	8	3
173	1230	10/28	36°40'N	171°38'E	65.7	000	14	60.2	55.0	1021.7	02	X	X	8	3
174	1530	10/28	36°13'N	171°36'E	70.3	010	15	65.0	59.0	1021.7	02	X	X	8	2
175	1830	10/28	35°45'N	171°32'E	68.5	060	07	63.7	57.3	1021.0	02	0	8	8	2
176	0035	10/29	35°09'N	171°32'E	70.0	130	13	66.0	60.5	1019.3	60	0	8	5	3
177	0400	10/29	34°33'N	171°32'E	68.7	090	21	72.0	59.6	1018.6	02	8	8	7	3
178	0730	10/29	34°01'N	171°31'E	70.3	125	25	67.5	61.9	1018.3	02	1	1	7	4
179	1130	10/29	33°32'N	171°30'E	72.2	166	27	66.0	63.2	1017.6	60	X	X	2	4

Table 2.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 17, September 17 to November 7, 1954 (For coded values see H. O. Pub. 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1954	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
180	1500	10/29	33°02'N	171°30'E	71.5	150	28	70.0	66.0	1016.3	02	X	8	X	4
181	1830	10/29	32°32'N	171°29'E	72.6	190	23	71.0	68.5	1016.6	50	0	9	3	4
182	2200	10/29	32°03'N	171°28'E	73.4	160	21	74.5	71.2	1017.6	02	0	9	4	4
183	0130	10/30	31°34'N	171°30'E	73.3	150	19	76.0	72.0	1015.6	02	6, 8, 1	7	8	4
184	0500	10/30	31°23'N	172°01'E	73.3	170	18	73.8	71.2	1016.3	02	1, 3, 8	6	8	4
185	1100	10/30	31°15'N	172°39'E	72.6	130	04	74.5	71.5	1017.6	02	X	X	8	3
186	1430	10/30	31°07'N	173°15'E	72.4	130	10	75.0	72.0	1015.6	02	X	X	3	2
187	1800	10/30	30°59'N	173°52'E	75.3	200	14	74.8	72.3	1016.6	60	0, 5	8	6	3
188	0000	10/31	30°50'N	174°32'E	75.9	170	20	77.0	73.5	1015.9	02	6, 5	7	8	3
189	0330	10/31	30°33'N	175°04'E	76.0	190	13	77.8	73.6	1014.9	02	5, 6	7	7	3
190	0700	10/31	30°15'N	175°36'E	76.2	190	14	77.0	73.2	1016.3	02	X	X	7	2
191	1305	10/31	30°04'N	176°10'E	77.6	145	16	77.0	73.9	1015.6	02	X	X	7	2
192	1630	10/31	29°53'N	176°43'E	78.2	200	12	76.0	71.6	1015.6	02	8	2	8	3
193	2010	10/31	29°39'N	177°19'E	77.8	205	18	77.8	72.1	1016.6	02	5	1	8	3
194	0130	11/1	29°23'N	177°49'E	74.4	185	14	76.2	70.6	1014.9	03	5	1	8	3
195	0505	11/1	29°08'N	178°22'E	74.8	220	11	75.8	70.5	1014.9	02	5	1	8	2
196	0755	11/1	28°55'N	178°50'E	74.9	220	13	75.6	70.0	1015.6	02	5	1	8	2
197	1300	11/1	28°40'N	179°20'E	75.8	190	16	75.3	70.5	1015.9	02	X	1	8	3
198	1600	11/1	28°26'N	179°47'E	75.3	200	05	75.0	69.5	1015.2	02	8	1	8	2
199	1900	11/1	28°11'N	179°43'W	75.1	260	10	75.1	69.7	1016.3	02	8	1	8	1
200	2330	11/1	28°03'N	179°10'W	77.0	250	11	77.9	71.1	1014.9	02	2, 8	1	8	1
201	0200	11/2	27°56'N	178°47'W	77.2	250	08	79.2	74.0	1015.2	02	5, 8	1	8	2
202	0430	11/2	27°49'N	178°22'W	77.4	270	10	77.7	71.9	1013.9	02	1, 8	2	8	2
203	0700	11/2	27°42'N	177°56'W	77.0	285	05	77.7	72.1	1014.9	02	8	2	8	1
204	0930	11/2	27°35'N	177°30'W	77.7	250	04	76.8	71.7	1014.9	02	8	2	8	1
205	1200	11/2	27°28'N	177°06'W	76.3	250	08	76.0	70.2	1015.6	02	X	1	8	2
206	1430	11/2	27°22'N	176°40'W	77.6	275	07	75.8	70.1	1013.9	02	X	1	8	1
207	1700	11/2	27°14'N	176°12'W	78.0	288	05	76.0	71.8	1014.2	02	8	2	8	1
208	1935	11/2	27°08'N	175°47'W	77.3	260	05	77.5	72.3	1015.6	02	1, 8	1	8	1
209	2200	11/2	27°02'N	175°27'W	77.5	250	10	78.0	72.0	1015.9	02	1, 8	3	8	3

Table 2.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 17, September 17 to November 7, 1954 (For coded values see H. O. Pub. 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1954	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Baro-meter, mb.	Wea-ther	Clouds		Visi-bili-ty	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
210	0030	11/3	26°53'N	175°02'W	77.6	260	07	79.9	74.7	1013.5	02	1, 8	4	8	2
211	0300	11/3	26°46'N	174°36'W	77.8	285	12	78.1	73.0	1012.9	01	1, 8	1	8	1
212	0530	11/3	26°37'N	174°10'W	76.7	290	10	79.8	75.4	1013.5	02	1, 8	1	8	2
213	0800	11/3	26°29'N	173°45'W	75.1	290	02	77.1	72.0	1016.3	02	1, 8	3	8	1
214	1030	11/3	26°21'N	173°21'W	75.3	245	04	75.7	72.8	1014.9	02	1, 8	1	8	1
215	1300	11/3	26°14'N	172°57'W	77.2	245	06	75.2	72.0	1014.2	02	1, 8	1	8	1
216	1530	11/3	26°04'N	172°34'W	78.9	285	09	77.3	72.0	1013.5	02	X	X	8	2
217	1800	11/3	25°55'N	172°09'W	78.5	340	12	76.0	72.6	1015.6	16	8, 9	8	7	2
218	0500	11/4	25°40'N	171°38'W	78.3	065	15	78.0	72.3	1013.9	01	2, 8	6	7	3
219	0730	11/4	25°27'N	171°16'W	78.1	095	14	78.0	73.2	1014.9	01	1, 5, 8	7	7	2
220	1000	11/4	25°13'N	170°54'W	79.0	060	12	74.7	73.2	1016.3	63	0	8	3	2
221	1230	11/4	24°59'N	170°33'W	79.0	030	10	75.0	72.4	1015.6	02	X	8	7	2
222	1500	11/4	24°49'N	170°12'W	78.8	010	05	76.7	73.3	1014.9	02	1, 8	8	7	2
223	1730	11/4	24°39'N	169°50'W	78.4	170	06	74.1	73.0	1015.9	58	1	9	5	1
224	2000	11/4	24°29'N	169°28'W	78.2	230	04	75.2	73.5	1016.9	02	1	7	8	2
225	2230	11/4	24°18'N	169°06'W	79.0	200	05	79.0	72.9	1015.9	02	0, 3, 1, 5	2	8	1
226	0100	11/5	24°09'N	168°44'W	79.5	210	08	78.0	72.6	1015.6	02	0, 3, 1, 5	2	8	1
227	0330	11/5	23°59'N	168°21'W	79.9	235	07	80.0	73.0	1016.9	02	1, 5, 8	1	8	1
228	0600	11/5	23°49'N	167°57'W	78.8	000	00	77.6	71.2	1016.6	02	1, 8	1	8	1
229	0830	11/5	23°40'N	167°34'W	78.4	000	00	76.8	70.1	1017.6	02	8	1	8	0
230	1100	11/5	23°33'N	167°10'W	78.8	100	02	76.9	70.5	1016.9	02	8	1	8	0
231	1330	11/5	23°26'N	166°43'W	78.0	135	05	76.9	71.5	1014.9	02	5	1	8	0
232	1600	11/5	23°20'N	166°18'W	78.4	160	03	76.2	71.5	1015.6	02	8	1	8	0
233	1830	11/5	23°14'N	165°54'W	78.1	090	10	78.1	70.7	1016.9	02	6, 8	1	8	1
234	2100	11/5	23°08'N	165°29'W	78.6	105	03	80.7	73.6	1017.3	02	6, 8	1	8	1
235	2330	11/5	23°01'N	165°02'W	79.9	105	05	81.7	75.4	1015.6	03	0, 4, 5, 8	7	8	0
236	0200	11/6	22°54'N	164°37'W	79.4	095	07	77.1	74.8	1015.2	02	8	1	8	0
237	0430	11/6	22°49'N	164°18'W	78.5	060	06	76.0	70.6	1016.3	02	8	1	8	1
238	0700	11/6	22°44'N	163°55'W	78.4	040	07	77.8	73.6	1017.3	01	X	0	8	0
239	0930	11/6	22°37'N	163°30'W	78.0	094	11	77.8	74.0	1020.0	03	4, 5, 8	1	8	1

Table 2.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 17, September 17 to November 7, 1954 (For coded values see H. O. Pub. 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1954	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Baro-meter, mb.	Wea-ther	Clouds		Visi-bili-ty	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
240	1200	11/6	22°31'N	163°07'W	77.9	095	07	78.1	73.0	1016.6	02	8	1	8	1
241	1430	11/6	22°25'N	162°44'W	78.1	060	10	77.0	71.0	1016.6	02	8	1	8	2
242	1700	11/6	22°20'N	162°20'W	78.9	040	18	83.2	78.6	1016.9	03	4, 5, 8	3	8	3
243	1930	11/6	22°14'N	161°55'W	79.2	090	17	78.3	75.5	1017.6	15	4, 5, 8, 9	5	8	2
244	2200	11/6	22°07'N	161°32'W	79.9	065	16	81.9	76.3	1016.9	02	8	3	8	1
245	0030	11/7	22°02'N	161°09'W	80.0	060	14	79.5	72.0	1015.2	02	8	1	8	3
246	0300	11/7	21°56'N	160°48'W	79.8	065	17	80.7	73.9	1014.9	02	8	1	8	3
247	0530	11/7	21°50'N	160°25'W	79.3	055	20	78.6	74.0	1016.3	03	4, 5, 8	2	8	2
248	0800	11/7	21°43'N	160°03'W	78.4	070	22	77.8	74.1	1017.3	02	8	2	8	2
249	1030	11/7	21°37'N	159°40'W	78.9	070	25	79.8	71.2	1016.9	03	8	3	8	3-4
250	1300	11/7	21°33'N	159°18'W	78.9	060	22	77.3	72.5	1015.9	03	8	3	8	3
251	1530	11/7	21°29'N	158°58'W	79.2	052	21	77.6	75.2	1016.3	02	8	1	8	3
252	1800	11/7	21°23'N	158°35'W	79.9	055	19	80.8	75.1	1017.3	02	8	3	8	3

Table 3.--Log of ship's weather observations, Charles H. Gilbert cruise 17, September 17 to November 7, 1954. Results in International Ship's Weather Code, January 1954

					Wind		Weather		Pressure			Temperature			Clouds						Waves		
Date, 1954	Latitude	Longitude	Time, GCT	Visibility	Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
9/19	22.9°N	160.0°W	0600	99	07	26	02	1	1014.6	3	1.0	78.0	70.4	78.6	X	X	X	X	X	X	07	4	4
9/19	23.7°N	160.0°W	1200	99	07	16	02	1	1014.9	8	1.0	78.2	73.8	77.9	1	1	1	6	0	0	07	3	3
9/20	24.7°N	160.0°W	0000	99	07	16	02	1	1013.5	8	1.0	78.2	71.7	78.4	2	2	2	6	0	0	07	2	1
9/20	25.3°N	160.0°W	0600	99	04	17	02	1	1014.6	3	1.2	75.2	69.8	77.2	1	1	8	7	4	0	04	2	2
9/20	25.8°N	160.0°W	1200	99	04	10	02	1	1014.9	8	0.6	76.0	72.8	76.9	1	1	2	7	0	0	04	2	1
9/20	26.8°N	160.0°W	1800	99	06	10	02	1	1015.2	3	1.2	75.9	69.9	77.0	3	3	2	6	0	0	06	2	2
9/21	27.2°N	160.0°W	0000	97	05	16	16	1	1015.9	8	0.6	74.8	71.2	78.5	7	5	6	6	0	2	05	3	2
9/21	28.3°N	160.0°W	0600	98	04	10	02	1	1014.2	3	1.6	76.2	73.0	77.3	4	3	2	5	0	2	04	2	1
9/21	28.6°N	160.0°W	1200	98	00	00	02	1	1017.6	8	0.8	75.2	72.0	76.6	X	X	X	X	X	X	09	2	0
9/21	29.8°N	160.0°W	1800	99	06	09	02	1	1018.0	3	0.8	74.7	70.8	75.6	2	1	1	5	0	9	03	3	1
9/22	30.4°N	160.0°W	0000	99	02	08	02	1	1018.0	0	0.6	77.2	71.0	77.8	2	2	5	5	0	0	03	3	2
9/22	31.2°N	160.0°W	0600	-	02	08	02	1	1018.3	3	1.4	77.4	72.8	76.8	3	3	8	6	0	0	03	3	2
9/22	31.6°N	160.0°W	1200	99	00	00	02	1	1018.3	8	0.3	74.0	69.7	75.7	0	0	0	9	0	0	03	2	1
9/22	32.5°N	160.0°W	1800	99	31	12	15	6	1018.0	3	0.0	72.4	69.3	75.3	4	2	3	6	6	0	33	2	2
9/23	33.2°N	160.0°W	0000	99	26	09	03	1	1016.9	8	1.2	75.0	73.5	75.0	4	2	8	5	2	0	30	2	2
9/23	34.1°N	160.0°W	0600	99	31	07	02	1	1014.9	8	0.8	75.2	72.1	75.0	3	2	2	5	6	1	32	3	3
9/23	34.6°N	160.0°W	1200	98	28	20	02	0	1015.2	9	1.0	73.9	71.0	73.9	0	0	0	9	0	0	28	3	3
9/23	35.4°N	160.0°W	1800	99	25	20	02	1	1013.5	6	0.3	74.3	71.1	73.9	3	3	2	5	3	1	26	3	3
9/24	37.0°N	160.0°W	0600	97	34	30	02	2	1010.8	5	0.4	75.3	75.0	74.0	5	5	7	5	0	0	34	3	7
9/24	37.9°N	160.0°W	1200	97	30	19	02	2	1012.5	3	2.0	69.5	68.5	72.0	9	9	X	0	X	X	34	3	4
9/24	38.9°N	160.0°W	1800	98	00	11	02	1	1015.2	5	1.7	68.3	63.8	71.5	7	0	0	9	7	0	26	4	3
9/25	39.1°N	160.0°W	0000	98	07	14	60	2	1017.6	1	0.6	69.1	63.8	71.4	8	6	6	4	2	X	24	3	5
9/25	39.7°N	160.2°W	0600	97	04	21	63	2	1016.6	1	0.8	66.0	62.2	70.2	8	7	3	4	2	X	04	2	5
9/25	40.6°N	160.3°W	1200	95	04	34	65	6	1016.9	9	1.0	63.3	62.8	70.0	9	9	X	0	X	X	04	3	6
9/25	40.8°N	160.7°W	1800	97	04	34	60	6	1016.6	4	0.8	61.5	59.4	69.5	8	8	7	4	X	X	04	4	6
9/26	41.0°N	160.7°W	0000	97	03	35	60	6	1015.9	8	1.4	61.0	59.8	67.5	8	8	7	4	X	X	03	4	9
9/26	41.6°N	160.6°W	0600	96	03	35	21	6	1015.9	5	0.0	62.0	59.8	67.0	8	8	7	4	X	X	03	4	9
9/26	42.0°N	160.0°W	1200	95	03	29	65	6	1014.9	6	2.0	59.5	59.0	66.5	9	9	X	0	X	X	03	4	7
9/26	42.0°N	160.2°W	1800	98	33	26	02	2	1014.6	0	0.0	62.0	60.2	65.1	8	8	7	4	X	X	01	4	7
9/27	42.0°N	160.0°W	0000	98	27	18	02	2	1012.5	6	2.1	66.1	61.3	65.6	6	6	4	5	0	0	29	3	5

Table 3.--Log of ship's weather observations, Charles H. Gilbert cruise 17, September 17 to November 7, 1954. Results in International Ship's Weather Code, January 1954 (cont'd)

					Wind		Weather		Pressure			Temperature			Clouds						Waves		
Date, 1954	Latitude	Longitude	Time, GCT	Visibility	Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
9/27	42.8°N	160.0°W	0600	97	35	10	50	1	1011.2	3	1.0	59.3	58.6	64.8	7	7	3	4	0	0	02	2	3
9/27	43.6°N	160.0°W	1200	-	15	04	02	0	1011.5	6	0.1	64.8	59.6	66.0	0	0	0	9	0	0	20	2	2
9/28	44.0°N	160.0°W	0000	98	14	27	21	6	1007.8	6	2.0	68.2	66.7	66.1	8	6	7	4	5	2	14	4	4
9/28	44.1°N	160.0°W	0600	98	14	34	02	2	1007.8	4	1.0	68.5	67.5	65.5	8	2	7	4	5	2	15	4	9
9/28	44.3°N	160.0°W	1800	98	14	26	02	2	1008.8	4	1.0	68.0	66.3	64.8	8	9	2	4	5	2	14	4	8
9/29	43.0°N	160.0°W	0000	98	15	38	02	2	1005.8	8	2.0	68.2	67.5	64.8	8	0	0	9	2	X	65	5	1
9/29	42.8°N	160.0°W	0600	97	14	39	02	2	1002.7	8	1.0	67.3	68.5	66.0	8	8	0	6	2	X	67	8	3
9/29	42.8°N	159.8°W	1800	94	14	34	02	2	997.6	5	0.7	65.2	64.7	65.5	8	8	7	3	X	X	65	5	4
9/30	43.2°N	159.8°W	0000	95	15	22	21	6	995.9	9	1.1	64.5	63.4	64.2	8	8	9	3	X	X	15	6	9
9/30	43.5°N	159.9°W	0600	96	14	20	62	1	996.3	3	0.0	65.1	64.9	65.0	6	4	7	4	8	6	14	5	9
9/30	44.1°N	160.0°W	1200	99	11	17	02	2	994.9	5	0.0	64.0	63.5	61.9	3	2	2	3	0	2	11	6	9
10/1	45.0°N	160.2°W	0000	98	12	20	02	2	961.4	3	0.0	63.8	62.0	61.0	8	2	3	4	2	X	62	8	0
10/1	45.0°N	161.5°W	0600	95	26	22	36	8	995.6	3	2.0	60.1	57.2	60.4	8	8	2	4	X	X	11	7	9
10/1	45.0°N	162.6°W	1200	98	23	21	01	1	998.6	1	0.6	59.9	55.9	60.0	2	2	1	5	0	0	23	4	6
10/1	45.0°N	163.6°W	1800	96	18	18	21	2	996.6	8	1.3	58.2	57.4	59.9	8	8	7	4	X	X	XX	X	X
10/2	45.0°N	164.3°W	0000	99	28	22	01	1	993.6	3	0.0	57.2	53.5	59.5	2	1	2	5	6	1	28	3	3
10/2	45.0°N	165.0°W	0600	98	22	26	02	1	995.9	3	2.0	57.5	53.0	58.8	4	3	5	6	2	0	22	3	6
10/2	45.0°N	165.9°W	1200	99	23	24	01	1	996.3	6	0.3	55.7	52.4	59.1	2	2	3	6	0	2	24	3	5
10/2	45.0°N	166.4°W	1800	99	27	36	62	1	998.3	4	1.3	52.2	50.2	57.3	3	2	2	6	0	2	27	5	7
10/3	45.0°N	166.8°W	0000	99	24	30	02	1	1000.0	3	1.7	55.8	51.8	57.5	3	3	4	6	0	0	24	3	8
10/3	44.8°N	167.5°W	0600	98	23	32	02	1	1002.7	3	2.7	55.0	51.3	56.3	7	7	4	5	0	0	24	3	7
10/3	44.6°N	168.0°W	1200	98	23	29	02	2	1003.4	3	0.0	54.8	52.7	56.5	X	X	X	X	X	X	23	3	7
10/3	44.4°N	168.5°W	1800	98	21	28	15	2	1005.1	3	1.6	55.0	53.2	56.0	8	8	4	4	X	X	21	3	6
10/4	44.1°N	169.2°W	0000	98	24	18	02	2	1006.8	0	1.7	59.0	55.8	56.2	6	5	4	4	4	1	24	3	7
10/4	43.6°N	169.7°W	0600	98	33	03	02	2	1005.4	6	0.2	56.9	55.0	57.0	8	4	4	4	6	X	28	3	5
10/4	43.1°N	169.9°W	1200	98	22	07	02	2	1009.1	3	2.0	58.2	56.1	57.0	8	8	6	4	X	X	27	2	1
10/4	42.3°N	170.0°W	1800	97	14	13	50	2	1012.5	3	1.6	60.2	59.6	59.1	8	8	6	4	X	X	24	2	2
10/5	41.6°N	170.0°W	0000	90	18	22	47	4	1014.6	3	1.0	61.7	61.9	59.8	X	X	X	X	X	X	23	3	6
10/5	41.0°N	169.8°W	0600	99	17	20	02	4	1013.9	3	0.0	63.0	62.7	60.0	1	0	0	9	7	1	19	2	3
10/5	40.6°N	169.8°W	1200	90	16	25	02	2	1011.2	6	1.8	64.8	63.6	61.7	6	X	X	X	X	X	16	3	6

Table 3.--Log of ship's weather observations, Charles H. Gilbert cruise 17, September 17 to November 7, 1954. Results in International Ship's Weather Code, January 1954 (cont'd)

Date, 1954	Latitude	Longitude	Time, GCT	Visibility	Wind		Wea-ther		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
10/5	40.0°N	169.9°W	1800	99	21	30	02	2	1009.5	1	1.1	66.0	65.0	65.1	8	8	7	4	X	X	21	3	5
10/6	39.6°N	170.0°W	0000	99	20	22	02	2	1011.2	2	0.6	67.8	66.0	64.8	7	0	0	9	0	8	21	2	7
10/6	38.8°N	170.0°W	0600	99	20	05	02	0	1013.5	3	1.2	66.0	65.0	64.9	1	0	0	9	3	0	19	2	3
10/6	38.4°N	170.0°W	1200	99	19	04	02	0	1013.9	0	0.0	64.8	63.9	64.7	X	X	X	X	X	X	19	2	1
10/6	37.7°N	170.0°W	1800	90	23	03	44	4	1014.2	3	0.6	64.3	64.3	64.6	8	X	X	X	X	X	23	3	3
10/7	37.7°N	170.0°W	0000	96	23	06	46	1	1014.6	8	1.0	65.0	65.0	65.4	7	0	0	9	0	7	23	3	3
10/7	37.1°N	170.1°W	0600	94	00	00	28	4	1012.5	4	0.3	68.5	68.0	69.9	9	9	X	0	X	X	21	2	0
10/7	36.4°N	170.1°W	1200	-	18	26	00	4	1012.5	0	0.0	71.7	70.0	68.0	0	0	0	9	0	0	20	3	4
10/7	35.6°N	170.1°W	1800	99	21	27	02	1	1014.9	4	1.3	72.2	70.0	70.0	5	5	1	4	0	0	21	3	3
10/8	34.8°N	170.1°W	0000	98	21	25	03	1	1015.2	3	0.2	73.6	71.0	70.3	7	7	3	X	0	0	21	3	4
10/8	34.1°N	170.2°W	0600	99	19	19	02	1	1016.3	3	1.3	74.0	72.0	72.2	3	2	5	4	0	8	19	2	2
10/8	33.5°N	170.2°W	1200	98	19	19	03	1	1018.6	3	0.8	73.8	72.0	72.0	5	2	3	5	2	3	19	2	3
10/8	32.7°N	170.3°W	1800	99	22	08	02	1	1022.4	3	2.7	75.8	73.3	73.8	1	1	1	4	0	0	22	2	1
10/9	32.1°N	170.3°W	0000	99	17	11	02	0	1022.7	8	1.0	77.0	73.9	74.9	1	1	8	X	0	0	25	4	3
10/9	31.2°N	170.2°W	0600	99	18	14	02	0	1024.0	4	2.0	76.1	73.9	75.0	0	0	0	9	0	0	22	3	2
10/9	30.6°N	170.2°W	1200	99	15	15	01	0	1025.4	3	0.0	76.4	74.0	75.2	1	0	0	9	3	0	16	3	2
10/9	30.0°N	170.2°W	1800	99	09	08	02	0	1025.7	3	2.0	77.0	74.0	76.4	1	1	1	4	0	0	09	2	0
10/10	29.9°N	171.2°W	0000	99	13	10	02	0	1027.4	0	0.6	81.0	74.6	76.8	1	1	8	4	0	0	18	3	3
10/10	29.7°N	172.1°W	0600	99	11	12	02	0	1026.4	3	1.1	77.3	73.0	77.3	1	1	2	4	0	1	13	3	2
10/10	29.5°N	172.9°W	1200	99	05	12	02	0	1028.1	3	0.0	78.0	74.1	77.0	1	1	1	4	0	0	05	3	2
10/10	29.3°N	173.9°W	1800	99	09	12	02	0	1029.8	3	1.0	78.2	72.5	76.6	1	1	1	4	0	0	10	4	2
10/11	28.8°N	175.5°W	0600	99	11	12	02	0	1024.4	5	0.6	81.3	73.9	78.0	3	3	2	5	0	0	14	3	3
10/11	28.5°N	176.4°W	1200	99	06	16	02	0	1025.1	0	0.8	77.0	72.9	77.0	1	1	1	5	0	0	06	3	4
10/15	28.6°N	178.1°W	0600	99	08	12	02	2	1019.6	4	0.7	76.4	72.9	78.4	8	8	6	5	X	X	04	2	1
10/15	28.9°N	178.6°W	1200	99	09	08	02	2	1020.7	6	0.7	76.0	72.8	77.4	6	6	4	5	0	0	XX	X	X
10/15	29.3°N	179.2°W	1800	99	06	05	02	0	1021.3	4	0.2	75.5	68.8	76.3	1	1	8	X	0	0	06	3	2
10/16	29.8°N	179.9°E	0000	99	15	10	02	0	1019.0	8	1.7	81.3	74.5	76.9	1	1	8	6	0	0	12	2	0
10/16	30.3°N	179.7°E	0600	99	00	00	02	1	1019.3	4	0.7	77.9	74.8	76.8	7	7	5	4	0	0	15	4	0
10/16	31.2°N	179.7°E	1200	99	18	05	02	1	1020.0	3	0.0	76.1	72.2	74.9	1	1	1	4	0	0	15	5	0
10/17	32.7°N	179.9°E	0000	99	08	16	03	1	1021.0	0	1.0	74.2	71.9	74.5	6	4	8	4	0	8	36	3	2

Table 3.--Log of ship's weather observations, Charles H. Gilbert cruise 17, September 17 to November 7, 1954. Results in International Ship's Weather Code, January 1954 (cont'd)

Date, 1954	Latitude	Longitude	Time, GCT	Visibility	Wind		Wea-ther		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
10/17	33.4°N	179.9°E	0600	99	10	16	03	1	1021.7	4	1.3	71.2	68.2	73.0	6	5	2	4	2	0	09	2	2
10/17	34.9°N	179.9°E	1800	99	17	12	03	1	1020.3	6	1.0	70.0	67.5	72.2	7	7	5	4	0	0	31	2	2
10/18	35.6°N	179.9°E	0000	99	16	15	02	2	1017.3	8	2.1	70.1	69.5	69.8	8	6	6	5	2	X	16	2	1
10/18	36.6°N	180.0°	0600	90	21	24	02	2	1010.8	8	1.8	71.1	68.9	68.0	9	9	X	0	X	X	21	2	3
10/18	36.4°N	180.0°	1200	95	20	26	80	2	1006.1	8	3.0	71.8	69.3	65.6	X	X	X	X	X	X	20	3	7
10/18	36.1°N	179.9°W	1800	95	20	35	80	2	1002.4	6	2.0	71.8	70.2	68.0	8	8	7	4	X	X	20	3	9
10/19	35.8°N	179.9°W	0000	96	23	17	16	2	1004.1	3	0.0	70.5	69.0	69.0	7	6	3	4	0	9	23	3	8
10/19	36.0°N	180.0°	0600	97	04	35	01	1	1011.5	3	5.2	62.6	60.9	68.7	6	6	4	4	0	0	05	4	9
10/19	36.2°N	179.8°W	1200	98	06	30	02	1	1018.6	3	1.2	62.7	56.0	66.6	6	X	X	X	X	X	06	3	7
10/19	36.4°N	179.6°W	1800	99	04	30	02	1	1022.4	3	2.0	60.5	59.2	65.2	8	6	2	4	6	1	06	3	7
10/20	37.0°N	179.6°W	0000	99	06	20	02	1	1026.4	0	0.4	59.8	53.5	63.0	4	3	4	4	8	0	06	3	6
10/20	37.5°N	179.8°W	0600	98	06	21	02	1	1028.8	3	1.2	60.0	52.2	63.8	4	4	4	4	8	8	06	3	6
10/20	38.3°N	180.0°	1200	98	07	10	02	1	1030.5	0	0.0	55.7	50.3	58.4	X	X	X	X	X	X	06	3	4
10/20	39.2°N	179.7°E	1800	99	07	06	01	2	1030.5	5	0.8	55.3	48.7	59.7	7	3	4	4	1	9	05	3	2
10/21	39.7°N	179.6°E	0000	99	17	20	02	1	1029.5	8	3.7	58.1	52.3	59.1	3	1	1	4	7	6	19	2	1
10/21	40.6°N	179.6°E	0600	99	20	27	02	1	1021.3	6	2.0	59.2	54.4	57.2	8	6	4	4	6	X	17	4	4
10/21	41.8°N	179.6°E	1200	90	20	42	51	6	1002.7	8	10.0	57.5	57.0	58.7	9	9	X	0	X	X	20	3	7
10/22	41.9°N	179.7°W	0000	99	04	37	02	1	1073.6	3	0.6	53.1	48.2	55.6	8	6	4	4	1	X	36	6	8
10/22	42.0°N	179.8°W	0600	98	29	49	15	1	1011.5	1	1.6	51.8	46.7	56.1	6	4	8	4	9	9	29	3	9
10/22	42.0°N	180.0°	1200	98	33	32	02	1	1014.9	1	1.1	57.0	47.2	55.9	1	1	1	4	0	0	33	4	9
10/22	42.1°N	179.9°E	1800	99	31	38	02	1	1016.6	3	1.3	50.2	47.7	55.9	2	1	1	4	0	0	32	4	8
10/23	42.5°N	179.8°E	0000	99	35	22	03	1	1015.6	7	2.0	50.0	45.0	53.0	8	8	3	4	X	X	01	4	8
10/23	43.3°N	179.8°E	0600	99	31	07	02	1	1014.6	6	0.6	48.0	46.8	52.1	8	7	4	4	3	X	31	4	4
10/23	44.1°N	179.8°E	1200	99	27	08	02	1	1011.5	8	2.1	47.2	46.5	49.1	X	X	X	X	X	X	36	5	4
10/23	44.8°N	179.8°E	1800	99	31	15	03	1	1008.8	6	0.8	46.3	42.9	48.5	2	2	4	4	0	8	36	5	2
10/24	45.0°N	178.7°E	0600	99	30	29	02	1	1013.9	1	3.0	44.8	40.0	49.0	2	2	2	4	0	0	30	4	4
10/24	45.0°N	177.7°E	1200	99	35	25	02	1	1019.3	3	2.0	44.0	41.9	48.1	X	X	X	X	X	X	34	4	6
10/24	44.9°N	176.4°E	1800	99	03	28	02	1	1023.4	3	2.4	45.6	41.9	47.2	8	4	4	4	6	X	04	4	5
10/25	45.0°N	174.8°E	0600	99	21	14	02	2	1020.0	8	1.7	48.4	45.1	48.9	8	8	4	4	X	X	22	4	2
10/25	45.0°N	173.5°E	1200	90	15	34	53	7	1008.5	8	6.8	48.0	46.0	49.7	9	9	X	0	X	X	17	3	5

Table 3.--Log of ship's weather observations, Charles H. Gilbert cruise 17, September 17 to November 7, 1954. Results in International Ship's Weather Code, January 1954 (cont'd)

Date, 1954	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
10/25	45.0°N	172.1°E	1800	99	29	27	02	2	988.5	8	3.7	49.0	45.1	48.9	3	3	2	4	0	0	29	3	5
10/26	44.5°N	171.7°E	0000	92	33	62	25	6	-	3	11.0	-	-	-	8	8	7	4	X	X	84	6	5
10/26	43.9°N	171.8°E	0600	96	34	38	25	6	1006.8	3	6.0	48.3	-	53.4	8	8	7	4	X	X	84	6	5
10/27	41.3°N	172.3°E	0600	98	31	25	15	2	1015.6	3	0.0	51.3	47.1	52.7	8	8	5	-	X	X	31	3	5
10/27	40.3°N	172.2°E	1200	98	27	25	50	5	1018.0	1	1.1	55.2	49.8	59.0	X	X	X	X	X	X	30	3	6
10/27	39.5°N	172.0°E	1800	99	30	27	02	2	1019.0	1	1.2	58.4	51.8	62.6	8	8	4	4	X	X	27	3	5
10/28	38.5°N	171.9°E	0000	99	30	28	01	2	1020.3	0	0.8	59.0	53.9	63.6	4	1	8	4	8	0	30	3	4
10/28	37.6°N	171.8°E	0600	99	34	21	02	2	1020.7	3	0.2	59.7	54.2	65.4	6	5	2	4	2	9	34	4	4
10/28	36.7°N	171.7°E	1200	99	31	17	02	2	1021.3	3	0.2	60.0	56.7	65.3	8	X	X	X	X	X	31	4	4
10/29	35.2°N	171.5°E	0000	96	13	13	60	2	1019.3	9	2.0	66.0	60.5	70.0	8	8	7	3	X	X	33	5	2
10/29	34.2°N	171.5°E	0600	98	10	17	02	2	1017.3	0	0.6	72.8	59.8	68.8	8	8	8	X	X	X	01	4	3
10/29	33.4°N	171.5°E	1200	93	17	27	60	2	1017.6	6	1.0	66.0	63.2	72.2	X	X	X	X	X	X	17	2	3
10/29	32.2°N	171.5°E	1800	94	19	23	50	2	1016.6	1	1.0	71.0	68.5	72.6	8	8	7	3	X	X	17	3	4
10/30	31.4°N	172.0°E	0600	99	17	18	01	2	1016.3	1	0.6	73.8	71.2	73.3	6	4	7	4	0	9	17	3	3
10/30	31.2°N	172.8°E	1200	99	13	04	02	2	1017.6	3	0.6	74.5	71.5	72.6	X	X	X	X	X	X	13	3	3
10/30	31.0°N	173.9°E	1800	97	20	14	60	2	1016.9	1	2.0	74.8	72.3	75.3	8	6	4	4	3	X	20	2	3
10/31	30.8°N	174.5°E	0000	99	17	20	02	2	1015.9	-	-	77.0	73.5	75.9	7	5	4	4	2	0	17	3	3
10/31	30.4°N	175.4°E	0600	99	19	14	01	1	1015.6	1	1.0	80.0	74.5	76.2	3	2	8	4	4	0	19	3	2
10/31	30.1°N	176.0°E	1200	99	16	14	01	1	1015.9	9	0.6	77.1	73.1	77.7	X	X	X	X	X	X	16	2	0
11/1	29.5°N	177.6°E	0000	99	19	15	03	0	1015.2	6	1.0	78.8	71.2	76.7	1	1	0	X	4	9	20	2	2
11/1	29.1°N	178.5°E	0600	99	22	11	02	0	1015.2	3	0.3	75.8	70.5	74.8	1	1	0	X	4	0	18	0	1
11/1	28.7°N	179.2°E	1200	99	22	12	02	0	1016.3	8	0.4	75.3	70.5	75.5	1	X	X	X	X	X	20	3	2
11/1	28.3°N	179.9°W	1800	99	26	10	02	0	1016.3	3	1.1	75.1	69.7	75.1	1	1	1	6	2	1	25	0	1
11/2	28.0°N	179.1°W	0000	99	25	11	02	0	1014.6	8	2.0	77.9	71.1	77.0	1	1	1	7	0	8	25	2	0
11/2	27.7°N	178.1°W	0600	99	27	10	02	0	1013.9	3	0.2	77.7	71.9	77.4	2	2	1	5	0	1	27	2	1
11/2	27.2°N	176.2°W	1700	99	29	05	02	1	1014.2	3	0.2	76.0	71.8	78.0	2	2	1	5	0	0	29	X	1
11/3	26.9°N	175.1°W	0000	99	26	07	02	1	1013.5	8	1.6	79.9	74.7	77.6	4	4	1	5	0	1	26	2	2
11/3	26.6°N	174.1°W	0600	99	29	10	02	1	1013.5	1	0.7	79.8	75.4	76.7	1	1	1	5	0	1	30	2	1
11/3	26.2°N	173.1°W	1200	99	25	04	02	0	1014.9	6	0.6	75.7	72.8	75.3	1	X	X	X	X	X	25	2	1
11/3	25.9°N	172.1°W	1800	98	34	12	16	2	1015.6	4	1.0	76.0	72.6	78.5	8	8	3	X	X	X	34	3	3

Table 3.--Log of ship's weather observations, Charles H. Gilbert cruise 17, September 17 to November 7, 1954. Results in International Ship's Weather Code, January 1954 (cont'd)

					Wind		Weather		Pressure			Temperature			Clouds						Waves		
Date, 1954	Latitude	Longitude	Time, GCT	Visibility	Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
11/4	25.6°N	171.5°W	0600	98	06	15	01	2	1013.9	3	0.2	78.0	72.3	78.3	7	2	1	4	9	6	06	3	3
11/4	25.0°N	170.5°W	1200	94	06	12	21	6	1015.9	9	0.7	74.7	73.2	79.0	6	6	7	X	0	0	XX	X	X
11/4	24.7°N	169.9°W	1700	96	17	06	58	5	1015.9	0	0.4	74.1	73.0	78.4	9	9	X	3	X	X	04	X	0
11/5	24.2°N	168.9°W	0000	99	20	05	02	0	1015.9	9	0.8	79.0	72.9	79.0	1	1	5	4	7	9	36	3	4
11/5	23.8°N	167.9°W	0600	99	21	05	02	0	1016.3	1	0.9	80.0	73.0	79.9	1	1	1	4	0	1	33	3	3
11/5	23.5°N	167.0°W	1200	99	10	02	02	0	1016.9	9	1.0	76.9	70.5	78.8	1	1	1	4	0	0	10	X	0
11/5	23.3°N	166.0°W	1800	99	09	10	02	0	1016.9	3	1.4	78.1	70.7	78.1	1	1	5	X	0	0	02	3	3
11/6	23.0°N	165.0°W	0000	99	11	05	03	1	1015.6	6	2.0	81.7	75.4	79.9	7	4	X	7	7	0	00	X	0
11/6	22.8°N	164.1°W	0600	99	06	06	02	0	1016.3	3	1.0	76.0	70.6	78.5	1	1	1	X	0	0	02	4	3
11/6	22.5°N	163.1°W	1200	99	10	09	02	0	1017.3	0	0.3	78.2	73.1	77.9	1	1	1	5	0	0	XX	X	X
11/6	22.3°N	162.2°W	1800	99	04	18	03	0	1016.9	3	1.2	83.2	78.6	78.9	3	1	2	5	7	1	04	3	2
11/7	22.0°N	161.2°W	0000	99	06	14	02	0	1015.2	8	2.0	79.5	72.0	80.0	1	1	1	4	0	0	02	4	3

NOTES ON TABLE 4, TABULATED OCEANOGRAPHIC DATA, HMS 27

Where more than one cast was made on a station, they are divided in the observed data by a horizontal line, and the cast number indicated by Roman numerals.

Weather is recorded in the ww (present weather) code given in the U. S. Weather Bureau circular M, eighth edition, Manual of Marine Meteorological Observations. Cloud cover is in tenths of the sky.

At stations 1 through 38 the wind velocity was measured with an anemometer approximately 15 meters above the sea surface. At the remainder of the stations, they were estimated according to the Beaufort scale and were converted to speed using range of the Beaufort force given in the Manual of Marine Meteorological Observations, circular M, table 3. The direction (given to the nearest 10°) is that from which the wind was blowing, measured through 360° from north.

The following abbreviations, when appended to values or lines in the tabulated data have the following meanings:

Q -- The value seems questionable, but was used in construction of the station curve.

P -- The value is poor, and while carried was not used in drawing the station curve.

NG -- The value is obviously in error, and was dropped from the tabulations.

PT -- Nansen bottle pretripped, and data was unuseable.

Table 4.--Oceanographic station data

STATION 1

M/V *Hugh M. Smith*: Cruise 27, 22°34'N., 159°38'W., January 6, 1955. Messenger time: 1943 GCT. Weather: 02, cloud coverage 3. Wind: 160°, 8 kt. Sea: 3-5 ft. Wire angle: 03°. BT slide: 1

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	24.33	35.19	23.71	5.27	0.21
53	23.94	35.26	23.88	5.02	0.37
105	22.22	35.32 Q	24.42 Q	4.97	0.35
158	20.13	35.26	24.94	4.88	0.34
215	18.17	34.97	25.23	4.82	0.39
320	12.21	34.25	25.99	4.59	1.11
430	08.55	34.14	26.53	3.89	1.84
533	06.56	34.13	26.81	2.44	2.69
644	05.56	34.23	27.02	1.59	2.82
859	04.56	34.40	27.27	1.21	2.74
1065	03.79	34.51	27.43	1.44	2.98
1065	03.74	34.51	27.44	-	-
1263	03.27	34.54	27.51	1.63	3.18

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	24.33	35.19	23.71	0.000	1.851
10	24.29	35.20	23.73	0.042	1.809
20	24.24	35.21	23.75	0.084	1.767
30	24.16	35.22	23.78	0.125	1.726
50	23.98	35.25	23.86	0.207	1.644
75	23.54	35.29	24.02	0.307	1.544
100	22.58	35.32	24.32	0.402	1.449
150	20.10	35.25	24.94	0.571	1.280
200	19.12	35.11	25.09	0.721	1.130
250	16.70	34.75	25.41	0.861	0.990
300	13.50	34.37	25.82	0.984	0.867
400	09.40	34.16	26.42	1.182	0.669
500	07.07	34.12	26.74	1.337	0.514
600	05.90	34.19	26.95	1.466	0.385
700	05.21	34.28	27.10	1.578	0.273
800	04.80	34.36	27.21	1.678	0.173
1000	03.99	34.48	27.40	1.851	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 2

M/V Hugh M. Smith: Cruise 27, 23°52'N., 162°29'W., January 7, 1955. Messenger time: first cast 2146 GCT, second cast 2253 GCT. Weather: 02, cloud coverage 1. Wind: 170°, 20 kt. Sea: 3-5 ft. Wire angle: first cast 15°, second cast not recorded. BT slide: 6

OBSERVED

	DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
I	0	23.63	35.32	24.01	5.21	0.19
	31	23.61	35.32	24.02	5.04	0.25
	67	23.61	35.34	24.03	5.18	0.26
II	104	23.45	35.37	24.10	4.98	0.28
	162	20.40	35.25	24.86	4.84	0.28
	229	18.30	34.97	25.19	4.75	0.37
	344	12.43	34.29	25.97	4.69	0.95
	464	08.50	34.05	26.47	4.20	1.60
	578	06.36	34.05	26.78	2.86	2.41
	692	05.28	34.29	27.10	1.78	2.84
	915	04.49	34.38	27.26	1.09	3.08
	1154	03.57	34.45	27.41	1.26	3.04
	1154	03.50	34.45	27.42	-	-
	1367	03.14	34.54	27.53	1.57	2.88

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	23.63	35.32	24.01	0.000	1.926
10	23.62	35.32	24.02	0.039	1.887
20	23.62	35.32	24.02	0.078	1.848
30	23.61	35.32	24.02	0.117	1.809
50	23.61	35.31	24.01	0.196	1.730
75	23.60	35.36	24.05	0.294	1.632
100	23.49	35.36	24.08	0.391	1.535
150	20.83	35.28	24.77	0.569	1.357
200	19.59	35.15	25.00	0.725	1.201
250	17.28	34.84	25.34	0.869	1.057
300	14.80	34.52	25.66	0.998	0.928
400	10.28	34.15	26.26	1.211	0.715
500	07.75	34.02	26.56	1.382	0.544
600	06.06	34.10	26.86	1.525	0.401
700	05.25	34.29	27.11	1.641	0.285
800	04.90	34.34	27.19	1.742	0.184
1000	04.12	34.41	27.33	1.926	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 4

M/V Hugh M. Smith: Cruise 27, 23°12'N., 165°03'W., January 8, 1955. Messenger time: 1738 GCT. Weather: 16, cloud coverage 3. Wind: 140°, 15 kt. Sea: 1-3 ft. Wire angle: 05°. BT slide: 10

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	23.42	35.26	24.03	4.56	0.20
22	23.26	35.34	24.14	5.16	0.21
54	23.04	35.35	24.21	5.19	0.18
107	21.63	35.35	24.60	5.08	0.20
127	20.74	35.21	24.74	5.04	0.23
219	17.27	34.85	25.35	4.93	0.39
PT	-	-	-	-	-
446	10.11	34.22	26.34	4.61	1.21
553	06.89	34.11	26.76	2.67	2.24
666	05.60	34.22	27.01	1.42	2.61
903	04.44	34.40	27.28	1.03	2.90
1183	03.64	34.49	27.44	1.44	2.95
1183	03.58	34.49	27.45	-	-
1424	03.14	34.54	27.53	1.65	2.73

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	23.42	35.26	24.03	0.000	1.873
10	23.33	35.33	24.11	0.039	1.834
20	23.27	35.34	24.13	0.077	1.796
30	23.19	35.35	24.16	0.115	1.758
50	23.07	35.36	24.21	0.190	1.683
75	22.79	35.38	24.30	0.282	1.591
100	22.20	35.38	24.47	0.372	1.501
150	19.82	35.13	24.93	0.537	1.336
200	17.88	34.92	25.26	0.684	1.189
250	16.28	34.72	25.49	0.818	1.055
300	14.72	34.54	25.70	0.942	0.931
400	11.58	34.31	26.15	1.160	0.713
500	08.14	34.11	26.58	1.336	0.537
600	06.28	34.15	26.87	1.477	0.396
700	05.33	34.28	27.09	1.594	0.279
800	04.80	34.36	27.21	1.695	0.178
1000	04.11	34.44	27.35	1.873	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 6

M/V Hugh M. Smith: Cruise 27, 22°29'N., 167°30'W., January 9, 1955. Messenger time: 1237 GCT. Weather: 64, cloud coverage 2. Wind: 120°, 18 kt. Sea: 1-3 ft. Wire angle: 07°. BT slide: 14

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	24.27	35.28	23.79	5.08	0.15
23	23.74	35.43	24.06	5.02	0.14
65	23.22	35.48	24.26	4.92	0.10
109	22.03	35.35	24.49	4.67	0.15
161	19.82	35.19	24.97	4.70	0.20
219	17.27	34.83	25.34	4.68	0.34
326	12.67	34.16	25.83	4.34	0.86
436	09.51	34.16	26.40	3.46	1.42
534	07.42	34.14	26.70	1.92	2.22
650	05.98	34.22	26.96	1.28	2.60
860	04.78	34.42	27.26	0.87	2.90
PT	-	-	-	-	-
PT	-	-	-	-	-

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	24.27	35.28	-	-	-
10	24.25	35.30	-	-	-
20	23.80	35.41	-	-	-
30	23.69	35.42	-	-	-
50	23.55	35.45	-	-	-
75	23.18	35.48	-	-	-
100	22.33	35.38	-	-	-
150	20.35	35.24	-	-	-
200	18.45	35.00	-	-	-
250	15.67	34.56	-	-	-
300	13.59	34.28	-	-	-
400	10.45	34.16	-	-	-
500	08.02	34.14	-	-	-
600	06.48	34.17	-	-	-
700	05.60	34.27	-	-	-
800	05.04	34.36	-	-	-

Table 4.--Oceanographic station data (cont'd)

STATION 7

M/V *Hugh M. Smith*: Cruise 27, 21°35'N., 170°18'W., January 10, 1955. Messenger time: 0640 GCT. Weather: 02, cloud coverage 2. Wind: 190°, 7 kt. Sea: 3-5 ft. Wire angle: 02°. BT slide: 18

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	25.00	35.19	23.50	4.89	0.23
19	24.54	35.26	23.70	4.84	0.22
52	24.52	35.28	23.72	4.82	0.17
100	22.68	35.32	24.29	4.86	0.20
156	20.95 Q	35.19	24.67 Q	4.38	0.31
156	20.79 Q	35.19	24.71 Q	-	-
210	17.96	35.01	25.31	4.30	0.42
311	12.33	34.14	25.88	4.44	0.92
417	08.72	34.14	26.51	3.55	1.69
520	06.84	34.20	26.83	1.77	2.57
626	05.58	34.27	27.05	1.13	2.75
835	04.59	34.47	27.32	1.07	2.89
1035	04.26	34.52	27.40	1.34	2.90
1241	03.76	34.56	27.48	1.54	2.69

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	25.00	35.19	23.51	0.000	1.840
10	24.77	35.23	23.61	0.043	1.797
20	24.53	35.26	23.70	0.086	1.754
30	24.53	35.28	23.72	0.128	1.712
50	24.52	35.28	23.72	0.212	1.628
75	24.50	35.28	23.72	0.317	1.523
100	22.68	35.32	24.29	0.416	1.424
150	21.03	35.20	24.66	0.592	1.248
200	18.55	35.06	25.20	0.747	1.093
250	15.85	34.61	25.50	0.882	0.958
300	12.98	34.18	25.78	1.004	0.836
400	09.12	34.14	26.45	1.202	0.638
500	07.18	34.18	26.77	1.354	0.486
600	05.83	34.24	27.00	1.479	0.361
700	05.02	34.38	27.20	1.584	0.256
800	04.63	34.46	27.31	1.674	0.166
1000	04.32	34.51	27.38	1.840	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 8

M/V Hugh M. Smith: Cruise 27, 20°41'N., 172°18'W., January 11, 1955. Messenger time: 0034 GCT. Weather: 62, cloud coverage 5. Wind: 020°, 20 kt. Sea: 5-8 ft. Wire angle: 22°. BT slide: 22

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	24.60	35.32	23.72	4.86	0.18
20	24.58	35.35	23.75	4.79	0.19
66	24.48	35.37	23.80	4.80	0.16
110	24.34	35.37	23.84	4.81	0.16
163	20.09	35.19	24.90	4.72	0.28
219	17.28	34.85	25.35	4.64	0.45
329	11.32	34.23	26.13	4.15	1.14
443	08.26	34.14	26.58	2.97	2.03
550	06.46	34.18	26.87	1.69	2.57
662	05.35	34.33	27.13	1.10	2.74
875	04.66	34.45	27.30	1.24	2.83
1091	03.96	34.54	27.45	1.63	2.68
1091	03.90	34.54	27.45	-	-
1296	03.41	34.51	27.47	1.85	2.52

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	24.60	35.32	23.72	0.000	1.827
10	24.60	35.34	23.74	0.042	1.785
20	24.58	35.35	23.75	0.083	1.744
30	24.55	35.38	23.79	0.125	1.702
50	24.51	35.38	23.80	0.208	1.619
75	24.47	35.38	23.81	0.311	1.516
100	24.41	35.38	23.83	0.414	1.413
150	20.45	35.22	24.83	0.597	1.230
200	18.08	34.96	25.24	0.746	1.081
250	15.30	34.62	25.63	0.878	0.949
300	12.38	34.32	26.01	0.991	0.836
400	09.28	34.15	26.43	1.179	0.648
500	07.22	34.15	26.74	1.333	0.494
600	05.90	34.25	26.99	1.460	0.367
700	05.12	34.38	27.19	1.566	0.261
800	04.82	34.43	27.27	1.659	0.168
1000	04.25	34.52	27.40	1.827	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 9

M/V *Hugh M. Smith*: Cruise 27, 20°50'N., 177°23'W., January 12, 1955. Messenger time: 1850 GCT. Weather: 02, cloud coverage 3. Wind: 070°, 22 kt. Sea: 5-8 ft. Wire angle: 25°. BT slide: 32

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	24.89	35.25	23.58	4.80	0.17
19	24.92	35.25	23.55	4.80	0.17
62	24.92	35.26	23.58	4.78	0.16
104	23.41	35.30	24.06	4.90	0.15
157	20.87	35.26	24.76	4.60	0.25
209	18.36	34.96	25.17	4.51	0.38
314	13.27	34.40	25.89	4.46	0.83
424	10.18	NG	-	NG	NG
530	07.12	34.14	26.75	2.34	2.35
635	05.80	34.23	26.99	1.44	2.50
844	04.96	34.43	27.25	1.24	2.76
1054	04.19	34.51	27.40	1.67	2.75
1054	04.12	34.51	27.41	-	-
1259	03.54	34.58	27.52	1.58	2.61

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	24.89	35.25	23.58	0.000	1.951
10	24.91	35.25	23.58	0.043	1.908
20	24.92	35.25	23.58	0.087	1.864
30	24.92	35.25	23.58	0.130	1.821
50	24.92	35.26	23.58	0.217	1.734
75	24.93	35.28	23.59	0.325	1.626
100	24.61	35.25	23.67	0.433	1.518
150	21.02	35.27	24.71	0.622	1.329
200	18.98	35.05	25.08	0.778	1.173
250	16.38	34.74	25.48	0.917	1.034
300	14.05	34.47	25.79	1.039	0.912
400	10.90	34.21	26.20	1.250	0.701
500	07.94	34.14	26.63	1.421	0.530
600	06.08	34.20	26.93	1.557	0.394
700	05.49	34.30	27.08	1.671	0.280
800	05.12	34.39	27.20	1.773	0.178
1000	04.35	34.49	27.37	1.951	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 10

M/V *Hugh M. Smith*: Cruise 27, 21°52'N., 179°58'E., January 13, 1955. Messenger time: 1355 GCT. Weather: 02, cloud coverage 3. Wind: 090°, 20 kt. Sea: not recorded. Wire angle: 25°. BT slide: 37

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	24.91	35.32	23.62	4.92	0.16
20	24.93	35.32	23.62	4.80	0.15
61	24.93	35.34	23.64	4.76	0.14
104	24.66	35.41	23.77	4.81	0.15
156	21.42	35.26	24.60	4.68	0.22
210	18.10	34.92	25.20	4.37	0.46
315	12.55	34.34	25.99	4.66	0.89
424	08.77	34.14	26.50	3.67	1.57
529	07.24	34.11	26.71	2.78	2.15
633	05.92	34.14	26.91	1.88	2.46
841	04.52	34.36	27.24	1.16	2.76
1051	03.92	34.51	27.43	1.43	2.85
1051	03.86	34.51	27.43	-	-
1254	03.38	34.56	27.52	1.67	2.64

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D\,1000 - \Delta D$ (dyn. m)
00	24.91	35.32	23.63	0.000	1.922
10	24.92	35.32	23.63	0.043	1.879
20	24.93	35.32	23.63	0.086	1.836
30	24.93	35.32	23.63	0.128	1.794
50	24.93	35.33	23.63	0.214	1.708
75	24.92	35.34	23.64	0.321	1.601
100	24.72	35.39	23.74	0.428	1.494
150	21.81	35.29	24.51	0.620	1.302
200	18.85	35.01	25.09	0.781	1.141
250	15.40	34.63	25.62	0.916	1.006
300	13.28	34.41	25.90	1.032	0.890
400	09.25	34.16	26.44	1.226	0.696
500	07.69	34.12	26.65	1.383	0.539
600	06.30	34.12	26.84	1.522	0.400
700	05.32	34.22	27.04	1.643	0.279
800	04.69	34.32	27.19	1.746	0.176
1000	04.02	34.48	27.39	1.922	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 11

M/V Hugh M. Smith: Cruise 27, 22°31'N., 177°29'E., January 14, 1955. Messenger time: 0707 GCT. Weather: 02, cloud coverage 9. Wind: 090°, 17 kt. Sea: 3-5 ft. Wire angle: 13°. BT slide: 41

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	24.70	35.37	23.73	4.83	0.17
41	24.70	35.37	23.73	4.85	0.16
82	24.43	35.46	23.88	4.81	0.12
122	22.86	35.08 P	24.06 P	4.91	0.16
164	20.86	35.25	24.73	4.64	0.25
209	18.93	35.34 P	25.32 P	4.74	0.29
312	14.60	34.54	25.72	4.87	0.61
420	11.04	34.27	26.22	4.44	1.14
521	08.43	34.13	26.54	3.58	1.83
628	06.48	34.11	26.81	2.46	2.31
836	04.52	34.31	27.20	1.05	2.88
1041	04.10	34.47	27.38	1.34	2.93
1041	04.02	34.47	27.39	-	-
1244	03.48	34.56	27.51	1.62	2.65

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	24.70	35.37	23.73	0.000	2.006
10	24.70	35.37	23.73	0.042	1.964
20	24.70	35.37	23.73	0.084	1.922
30	24.70	35.37	23.73	0.125	1.881
50	24.68	35.37	23.74	0.209	1.797
75	24.49	35.45	23.86	0.313	1.693
100	24.39	35.46	23.89	0.414	1.592
150	21.35	35.30	24.65	0.600	1.406
200	19.35	35.05	24.99	0.760	1.246
250	17.12	34.82	25.37	0.904	1.102
300	15.05	34.58	25.66	1.032	0.974
400	11.68	34.32	26.14	1.252	0.754
500	08.90	34.15	26.49	1.433	0.573
600	06.98	34.10	26.73	1.586	0.420
700	05.50	34.17	26.98	1.715	0.291
800	04.67	34.28	27.16	1.823	0.183
1000	04.18	34.44	27.34	2.006	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 12

M/V Hugh M. Smith: Cruise 27, 23°18'N., 174°46'E., January 15, 1955. Messenger time: 0051 GCT. Weather: 02, cloud coverage 1. Wind: 080°, 13 kt. Sea: 3-5 ft. Wire angle: 00°. BT slide: 45

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	23.91	35.50	24.07	4.92	0.10
22	23.75	35.48	24.10	4.89	0.07
65	23.68	35.50	24.13	4.85	0.07
107	21.74	35.25	24.50	5.06	0.11
161	18.34	34.90	25.13	5.01	0.23
218	16.40	34.69	25.44	4.88	0.40
325	13.98	34.49	25.81	4.90	0.65
436	10.70	34.23	26.25	4.57	1.10
542	08.08	34.11	26.59	3.40	1.87
650	06.41	34.09	26.79	2.76	2.16
870	04.57	34.33	27.21	1.09	2.80
1081	03.86	34.49	27.42	1.26	2.89
1081	03.79	34.49	27.42	-	-
1295	03.40	34.54	27.50	1.63	2.60

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	23.91	35.50	24.07	0.000	1.925
10	23.79	35.49	24.09	0.038	1.887
20	23.76	35.48	24.10	0.077	1.848
30	23.76	35.49	24.10	0.115	1.810
50	23.75	35.50	24.11	0.192	1.733
75	23.66	35.50	24.14	0.287	1.638
100	22.25	35.30	24.40	0.380	1.545
150	18.95	34.96	25.02	0.544	1.381
200	16.82	34.74	25.38	0.686	1.239
250	15.49	34.61	25.58	0.815	1.110
300	14.42	34.53	25.75	0.935	0.990
400	11.80	34.32	26.12	1.152	0.773
500	09.02	34.16	26.48	1.335	0.590
600	07.10	34.09	26.71	1.489	0.436
700	05.83	34.14	26.92	1.623	0.302
800	05.00	34.24	27.09	1.737	0.188
1000	04.02	34.44	27.36	1.925	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 14

M/V Hugh M. Smith: Cruise 27, 23°57'N., 172°36'E., January 15, 1955. Messenger time: 1720 GCT. Weather: 60, cloud coverage 8. Wind: 060°, 30 kt. Sea: 8-12 ft. Wire angle: 28°. BT slide: 49

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	24.84	35.41	23.72	5.14	0.20
41	24.82	35.41	23.72	4.80	0.14
82	24.77	35.44	23.76	4.79	0.11
117	22.68	35.39	24.34	5.01	0.12
157	21.15	35.35	24.73	4.71	0.20
198	19.95	35.21	24.95	4.65	0.32
298	16.34	34.69	25.45	4.89	0.41
403	13.86	NG	NG	NG	NG
504	10.88	34.25	26.23	4.43	1.16
602	08.40	34.13	26.55	3.62	1.64
809	05.12	34.18	27.03	1.48	2.52
1003	04.28	34.38	27.29	1.23	2.70
1003	04.23	34.38	27.29	-	-
1205	03.66	34.52	27.46	1.47	2.72

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	24.84	35.41	23.72	0.000	2.156
10	24.83	35.41	23.72	0.042	2.114
20	24.83	35.41	23.72	0.084	2.072
30	24.82	35.41	23.73	0.126	2.030
50	24.81	35.42	23.74	0.210	1.946
75	24.78	35.44	23.76	0.314	1.842
100	24.41	35.44	23.87	0.417	1.739
150	21.40	35.36	24.68	0.603	1.553
200	19.90	35.20	24.96	0.763	1.393
250	17.50	34.83	25.28	0.909	1.247
300	16.29	34.68	25.45	1.044	1.112
400	13.98	34.45	25.79	1.292	0.864
500	11.01	34.26	26.22	1.504	0.652
600	08.44	34.13	26.55	1.681	0.475
700	06.46	34.09	26.80	1.829	0.327
800	05.20	34.18	27.02	1.953	0.203
1000	04.28	34.38	27.29	2.156	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 16

M/V Hugh M. Smith: Cruise 27, 25°00'N., 169°30'E., January 16, 1955. Messenger time: 1519 GCT. Weather: 02, cloud coverage 3. Wind: 080°, 21 kt. Sea: 3-5 ft. Wire angle: 22°. BT slide: 54

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	22.51	35.23	24.27	5.06	0.11
45	22.52	35.21	24.25	5.06	0.13
89	21.84	35.12	24.38	5.13	0.14
128	18.04	34.88	25.19	5.02	0.29
171	16.85	34.76	25.38	5.01	0.39
216	16.29	34.70	25.47	5.12	0.47
324	14.94	34.60	25.70	4.76	0.63
437	11.81	34.34	26.13	4.63	1.10
546	09.00	34.18	26.50	4.29	1.61
653	06.78	34.11	26.77	3.15	2.15
867	04.48	34.25	27.16	1.25	2.89
1078	03.47	34.40	27.38	0.87	3.12
1078	03.42	34.40	27.39	-	-
1284	03.03	34.52	27.52	1.22	3.03

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	22.51	35.23	24.27	0.000	1.944
10	22.51	35.23	24.27	0.037	1.907
20	22.51	35.22	24.26	0.073	1.871
30	22.51	35.22	24.26	0.110	1.834
50	22.50	35.20	24.25	0.184	1.760
75	22.49	35.20	24.25	0.277	1.667
100	19.89	35.03	24.83	0.363	1.581
150	17.39	34.82	25.30	0.510	1.434
200	16.46	34.72	25.45	0.643	1.301
250	15.95	34.68	25.53	0.772	1.172
300	15.34	34.62	25.62	0.897	1.047
400	12.85	34.42	25.99	1.126	0.818
500	10.13	34.22	26.34	1.322	0.622
600	07.79	34.13	26.64	1.487	0.457
700	06.08	34.12	26.87	1.626	0.318
800	05.00	34.19	27.06	1.746	0.198
1000	03.80	34.34	27.30	1.944	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 17

M/V Hugh M. Smith: Cruise 27, 26°30'N., 169°35'E., January 17, 1955. Messenger time: 0345 GCT. Weather: 02, cloud coverage 1. Wind: 100°, 16 kt. Sea: 3-5 ft. Wire angle: 05°. BT slide: 57

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	21.64	35.37	24.62	5.10	0.12
43	21.48	35.37	24.67	5.09	0.11
85	21.51	35.37	24.65	5.12	0.13
128	18.24	34.90	25.15	5.02	0.28
171	16.78	34.76	25.40	5.06	0.34
218	15.94	34.69	25.54	5.04	0.48
325	14.26	34.52	25.78	4.84	0.70
438	12.04	34.38	26.12	4.82	1.03
544	09.47	34.20	26.44	4.34	1.52
654	06.96	34.07	26.71	3.86	2.01
871	04.66	34.18	27.08	1.52	2.86
1079	03.62	34.38	27.35	0.85	3.19
1079	03.57	34.38	27.36	-	-
1287	03.04	34.42	27.44	0.94	3.11

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	21.64	35.37	24.62	0.000	1.921
10	21.62	35.37	24.62	0.033	1.888
20	21.59	35.37	24.63	0.067	1.854
30	21.51	35.37	24.65	0.100	1.821
50	21.47	35.37	24.67	0.166	1.755
75	21.48	35.37	24.66	0.249	1.672
100	20.65	35.26	24.81	0.330	1.591
150	17.30	34.81	25.32	0.477	1.444
200	16.21	34.71	25.50	0.609	1.312
250	15.45	34.64	25.61	0.735	1.186
300	14.71	34.56	25.71	0.855	1.066
400	12.82	34.44	26.01	1.079	0.842
500	10.63	34.29	26.31	1.276	0.645
600	08.05	34.12	26.60	1.445	0.476
700	06.23	34.09	26.83	1.589	0.332
800	05.20	34.14	26.99	1.713	0.208
1000	03.96	34.32	27.27	1.921	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 19

M/V Hugh M. Smith: Cruise 27, 27°56'N., 169°50'E., January 17, 1955. Messenger time: 1558 GCT. Weather: 02, clear. Wind: 150°, 8 kt. Sea: 3-5 ft. Wire angle: 14°. BT slide: 60

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	21.33	35.37	24.70	5.09	0.14
41	21.35	35.34	24.67	5.14	0.13
83	20.78	35.35	24.83	5.30	0.13
124	19.20	34.97	24.96	5.09	0.23
NG	-	-	-	-	-
213	16.05	34.69	25.52	5.07	0.49
317	14.56	34.54	25.73	4.88	0.65
426	12.18	34.34	26.07	4.76	0.94
530	09.60	34.22	26.43	4.46	1.45
638	07.33	34.09	26.68	3.47	1.97
638	07.27	34.09	26.69	-	-
850	04.90	34.16	27.04	1.78	2.68
1060	03.86	34.29	27.26	0.91	3.04
1060	03.81	34.29	27.26	-	-
1269	03.14	34.42	27.43	0.90	3.02

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	21.33	35.37	24.70	0.000	1.931
10	21.33	35.36	24.70	0.033	1.898
20	21.33	35.35	24.69	0.065	1.866
30	21.34	35.34	24.68	0.098	1.833
50	21.32	35.34	24.68	0.164	1.767
75	20.90	35.35	24.81	0.244	1.687
100	20.75	35.35	24.85	0.324	1.607
150	17.80	34.85	25.23	0.472	1.459
200	16.38	34.72	25.46	0.607	1.324
250	15.47	34.63	25.60	0.733	1.198
300	14.80	34.57	25.70	0.855	1.076
400	12.85	34.39	25.97	1.081	0.850
500	10.35	34.26	26.33	1.279	0.652
600	07.98	34.11	26.60	1.447	0.484
700	06.40	34.09	26.80	1.591	0.340
800	05.28	34.14	26.98	1.717	0.214
1000	04.08	34.25	27.20	1.931	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 20

M/V Hugh M. Smith: Cruise 27, 29°33'N., 169°57'E., January 18, 1955. Messenger time: 0610 GCT. Weather: 02, cloud coverage 5. Wind: 250°, 16 kt. Sea: 3-5 ft. Wire angle: 30°. BT slide: 63

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	21.70	35.17	24.45	5.08	0.11
34	21.58	35.16	24.47	5.05	0.13
69	19.77	NG	NG	NG	NG
103	19.56	34.88	24.80	4.97	0.20
137	19.17 Q	34.85	24.88	4.76	0.31
137	19.05 Q	34.85	24.91	-	-
176	17.01	34.69	25.29	4.79	0.44
262	15.79	34.60	25.51	4.91	0.48
354	14.34	34.51	25.75	4.79	0.69
442	12.91	34.36	25.93	4.83	0.90
533	10.66	34.22	26.25	4.63	1.23
717	06.16	34.02	26.78	3.44	2.22
903	04.33	34.14	27.09	1.49	2.97
903	04.27	34.14	27.09	-	-
1102	03.50	34.29	27.29	0.80	3.05

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	21.70	35.17	24.45	0.000	2.027
10	21.68	35.17	24.46	0.035	1.992
20	21.62	35.16	24.46	0.070	1.957
30	21.59	35.16	24.47	0.105	1.922
50	20.58	35.02	24.64	0.173	1.854
75	19.67	34.90	24.79	0.254	1.773
100	19.58	34.88	24.80	0.334	1.693
150	18.61	34.80	24.99	0.489	1.538
200	16.65	34.66	25.35	0.632	1.395
250	15.89	34.61	25.49	0.764	1.263
300	15.33	34.58	25.59	0.891	1.136
400	13.61	34.43	25.85	1.129	0.898
500	11.58	34.28	26.13	1.343	0.684
600	08.80	34.12	26.48	1.526	0.501
700	06.45	34.02	26.74	1.680	0.347
800	05.12	34.06	26.94	1.811	0.216
1000	03.80	34.23	27.22	2.027	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 22

M/V Hugh M. Smith: Cruise 27, 31°07'N., 170°35'E., January 18, 1955. Messenger time: 1828 GCT. Weather: 02, cloud coverage 5. Wind: 270°, 20 kt. Sea: 3-5 ft. Wire angle: 31°. BT slide: 66

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	19.86	34.85	24.75	5.19	0.14
38	19.86	34.83	24.74	5.24	0.14
77	19.40	34.78	24.77	5.19	0.15
110	18.18	34.76	25.07	5.06	0.26
150	16.74	34.70	25.36	4.94	0.38
189	16.28	34.72	25.49	4.96	0.45
286	15.14	34.60	25.65	4.72	0.63
386	13.15	34.45	25.96	4.87	0.84
386	13.34	34.45	25.92	-	-
482	11.30	34.33	26.22	4.63	1.16
580	08.62	34.14	26.52	4.52	1.56
771	05.04	34.02	26.92	2.90	2.49
967	03.96	34.22	27.19	1.20	2.96
967	03.90	34.22	27.20	-	-
1160	03.25	34.40	27.40	0.76	2.97

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	19.86	34.85	24.70	0.000	1.931
10	19.86	34.84	24.70	0.033	1.898
20	19.86	34.84	24.70	0.065	1.866
30	19.86	34.83	24.69	0.098	1.833
50	19.86	34.83	24.69	0.163	1.768
75	19.45	34.78	24.76	0.245	1.686
100	18.87	34.78	24.91	0.324	1.607
150	16.74	34.70	25.36	0.468	1.463
200	16.15	34.70	25.50	0.598	1.333
250	15.59	34.64	25.58	0.724	1.207
300	14.89	34.59	25.70	0.846	1.085
400	12.98	34.43	25.97	1.072	0.859
500	10.81	34.30	26.28	1.272	0.659
600	08.12	34.10	26.57	1.444	0.487
700	06.09	33.96	26.74	1.593	0.338
800	04.73	34.05	26.98	1.722	0.209
1000	03.79	34.25	27.23	1.931	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 24

M/V Hugh M. Smith: Cruise 27, 29°33'N., 179°20'E., February 2, 1955. Messenger time: 0425 GCT. Weather: 61, cloud coverage 8. Wind: 220°, 18 kt. Sea: 3-5 ft. Wire angle: 13°. BT slide: 91

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	19.02	34.92	24.97	5.67	0.18
41	19.04	34.88	24.94	5.37	0.15
82	19.06	34.85	24.91	5.30	0.16
123	18.58	34.78	24.98	5.22	0.21
164	17.78 Q	34.69 Q	25.11 Q	5.02 Q	0.43 Q
210	15.07	34.51	25.60	5.02	0.58
313	13.38	34.51	25.95	4.92	0.79
421	11.31	34.25	26.15	4.88	1.07
421	11.47	34.25	26.12	-	-
524	08.62	34.11	26.50	4.64	1.57
631	06.32	33.93	26.69	3.88	2.04
841	04.36	34.14	27.09	1.63	2.81
1045	03.57	34.33	27.32	0.72	3.16
1254	03.16	34.34	27.36	0.65	3.08

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	19.02	34.92	24.97	0.000	1.839
10	19.02	34.91	24.97	0.030	1.809
20	19.03	34.90	24.96	0.060	1.779
30	19.03	34.89	24.95	0.090	1.749
50	19.05	34.88	24.94	0.151	1.688
75	19.06	34.86	24.92	0.227	1.612
100	18.91	34.83	24.93	0.304	1.535
150	17.92	34.71	25.09	0.454	1.385
200	15.45	34.53	25.53	0.590	1.249
250	14.25	34.51	25.77	0.711	1.128
300	13.58	34.51	25.91	0.823	1.016
400	11.86	34.30	26.09	1.033	0.806
500	09.28	34.14	26.42	1.220	0.619
600	06.88	33.94	26.62	1.381	0.458
700	05.39	34.00	26.86	1.521	0.318
800	04.60	34.10	27.03	1.641	0.198
1000	03.67	34.31	27.29	1.839	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 26

M/V *Hugh M. Smith*: Cruise 27, 31°10'N., 179°52'E., February 2, 1955. Messenger time: 1835 GCT. Weather: 02, cloud coverage 6. Wind: 320°, 12 kt. Sea: 3-5 ft. Wire angle: 05°. BT slide: 94

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	18.80	34.90	25.01	5.29	0.14
43	18.80	34.90	25.01	5.34	0.14
PT	-	-	-	-	-
128	16.96	34.74	25.34	5.02	0.36
171	16.24	34.69	25.47	4.91	0.47
220	15.62	34.70	25.62	4.90	0.55
326	13.92	34.52	25.85	5.04	0.62
438	12.18	34.40	26.11	5.10	0.86
544	10.14	34.25	26.36	4.82	1.20
657	07.44	34.07	26.64	4.21	1.76
875	04.50	34.07	27.02	1.83	2.72
1084	03.70	34.16	27.17	1.27	2.90
1084	03.64	34.16	27.17	-	-
1300	03.12	34.34	27.37	0.64	3.00

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D\,1000 - \Delta D$ (dyn. m)
00	18.80	34.90	25.01	0.000	1.911
10	18.80	34.90	25.01	0.030	1.881
20	18.80	34.90	25.01	0.059	1.852
30	18.80	34.90	25.01	0.089	1.822
50	18.80	34.90	25.01	0.148	1.763
75	18.70	34.89	25.03	0.222	1.689
100	17.48	34.78	25.25	0.294	1.617
150	16.60	34.71	25.40	0.429	1.482
200	15.88	34.70	25.56	0.557	1.354
250	15.17	34.64	25.68	0.679	1.232
300	14.35	34.55	25.78	0.796	1.115
400	12.79	34.45	26.03	1.016	0.895
500	11.03	34.31	26.25	1.215	0.696
600	08.80	34.16	26.51	1.391	0.520
700	06.62	34.00	26.70	1.546	0.365
800	05.15	34.01	26.90	1.681	0.230
1000	03.99	34.12	27.11	1.911	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 27

M/V Hugh M. Smith: Cruise 27, 32°32'N., 179°56'W., February 3, 1955. Messenger time: 0505 GCT. Weather: 15, cloud coverage 7. Wind: 290°, 19 kt. Sea: 5-8 ft. Wire angle: 40°. BT slide: 97

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	18.47	34.94	25.13	5.45	0.14
35	18.49	34.94	25.12	5.41	0.15
69	18.52	34.92	25.10	5.35	0.13
100	18.48	34.92	25.11	5.34	0.14
134	18.18	34.92	25.19	5.25	0.23
168	16.41	34.65	25.40	4.92	0.46
252	15.38	34.58	25.59	4.94	0.49
339	14.00	34.52	25.83	4.78	0.74
423	12.46	34.38	26.04	4.90	0.91
505	10.28	34.23	26.32	4.71	1.22
669	06.68	33.98	26.68	4.33	1.86
834	04.72	34.04	26.97	2.28	2.64
834	04.67	34.04	26.98	-	-
990	03.87	34.20	27.18	1.02	2.93

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D\,1000 - \Delta D$ (dyn. m)
00	18.47	34.94	25.13	0.000	1.910
10	18.48	34.94	25.13	0.028	1.882
20	18.48	34.94	25.13	0.057	1.853
30	18.49	34.94	25.12	0.086	1.824
50	18.50	34.93	25.11	0.143	1.767
75	18.49	34.92	25.11	0.215	1.695
100	18.48	34.92	25.11	0.287	1.623
150	16.80	34.70	25.35	0.427	1.483
200	15.99	34.61	25.47	0.558	1.352
250	15.39	34.58	25.58	0.685	1.225
300	14.87	34.56	25.68	0.807	1.103
400	12.93	34.43	25.98	1.034	0.876
500	10.42	34.24	26.31	1.233	0.677
600	08.00	34.06	26.56	1.404	0.506
700	06.26	33.96	26.72	1.554	0.356
800	05.05	34.00	26.90	1.688	0.222
1000	03.87	34.20	27.19	1.910	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 29

M/V *Hugh M. Smith*: Cruise 27, 36°43'N., 179°30'E., February 4, 1955. Messenger time: 2115 GCT. Weather: 02, cloud coverage 4. Wind: 060°, 21 kt. Sea: 8-12 ft. Wire angle: 10°. BT slide: 105

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	15.03	34.56	25.56	5.73	0.31
48	15.00	34.54	25.64	5.72	0.31
96	14.13	34.49	25.78	5.23	0.54
138	13.50	34.42	25.86	5.26	0.57
185	12.60	34.42	26.04	5.20	0.74
233	12.10	34.36	26.09	4.82	0.90
350	10.09	34.22	26.35	4.36	1.13
472	07.95	34.07	26.57	4.67	1.46
589	05.68	33.93	26.77	3.85	1.98
705	04.66	34.02	26.96	1.86	2.37
931	03.84	34.22	27.20	1.30	2.71
1158	03.22	34.34	27.36	0.76	2.93
1158	03.17	34.34	27.36	-	-
1373	02.81	34.42	27.46	0.72	2.85

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	15.03	34.56	25.65	0.000	1.561
10	15.02	34.56	25.65	0.024	1.537
20	15.02	34.55	25.64	0.047	1.514
30	15.01	34.55	25.64	0.071	1.490
50	15.00	34.54	25.64	0.118	1.443
75	14.92	34.53	25.65	0.178	1.383
100	14.08	34.49	25.80	0.235	1.326
150	13.33	34.42	25.90	0.345	1.216
200	12.41	34.40	26.06	0.449	1.112
250	11.92	34.35	26.12	0.548	1.013
300	11.12	34.29	26.22	0.644	0.917
400	09.16	34.16	26.46	0.821	0.740
500	07.42	34.02	26.61	0.980	0.581
600	05.53	33.94	26.80	1.122	0.439
700	04.72	34.02	26.95	1.248	0.313
800	04.32	34.11	27.07	1.361	0.200
1000	03.65	34.26	27.25	1.561	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 30

M/V Hugh M. Smith: Cruise 27, 37°13'N., 177°36'W., February 5, 1955. Messenger time: 1441 GCT. Weather: 02, cloud coverage 5. Wind: 050°, 15 kt. Sea: 8-12 ft. Wire angle: 00°. BT slide: 108

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	14.87	34.58	25.70	5.71	0.27
42	14.87	34.60	25.71	5.65	0.26
84	14.55	34.52	25.72	5.65	0.31
126	14.28	34.51	25.77	5.67	0.31
168	14.02	34.51	25.82	5.75	0.34
215	13.74	34.47	25.85	5.82	0.40
320	12.68	34.42	26.03	5.14	0.67
429	11.00	34.31	26.26	5.17	0.88
534	09.46	34.22	26.45	5.22	1.10
642	07.54	34.09	26.65	4.40	1.51
857	04.84	34.00	26.92	2.40	2.35
1064	03.82	NG	NG	NG	NG
1275	03.26	NG	NG	NG	NG

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	14.87	34.58	25.70	0.000	1.753
10	14.87	34.58	25.70	0.023	1.730
20	14.87	34.59	25.70	0.046	1.707
30	14.87	34.60	25.71	0.069	1.684
50	14.87	34.60	25.71	0.115	1.638
75	14.70	34.54	25.70	0.173	1.580
100	14.41	34.52	25.75	0.231	1.522
150	14.15	34.50	25.79	0.344	1.409
200	13.78	34.48	25.85	0.456	1.297
250	13.61	34.46	25.87	0.566	1.187
300	12.99	34.43	25.97	0.675	1.078
400	11.47	34.34	26.20	0.877	0.876
500	10.00	34.25	26.39	1.060	0.693
600	08.29	34.15	26.58	1.226	0.527
700	06.61	34.01	26.71	1.377	0.376
800	05.36	33.97	26.84	1.514	0.239
1000	04.12	34.10	27.08	1.753	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 31

M/V *Hugh M. Smith*: Cruise 27, 37°00'N., 175°30'W., February 6, 1955. Messenger time: 0513 GCT. Weather: 02, cloud coverage 4. Wind: 120°, 16 kt. Sea: 5-8 ft. Wire angle: 35°. BT slide: 111

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	14.88	34.58	25.69	5.66	0.36
31	14.90	34.60	25.71	5.66	0.30
63	14.92	34.58	25.69	5.65	0.35
95	14.90	34.58	25.69	5.66	0.35
126	14.85	34.60	25.72	5.63	0.33
162	14.88	34.58	25.69	5.65	0.42
243	13.60	34.47	25.88	5.12	0.58
327	12.43	34.40	26.06	5.22	0.77
407	11.14	34.33	26.25	5.32	0.90
495	09.66	34.18	26.39	5.25	1.11
661	06.44	34.00	26.73	4.02	1.88
828	04.58	34.09	27.02	2.04	2.56
1006	03.90	34.23	27.21	1.14	2.81

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	14.88	34.58	25.69	0.000	1.709
10	14.88	34.59	25.70	0.023	1.686
20	14.89	34.59	25.70	0.046	1.663
30	14.90	34.60	25.70	0.069	1.640
50	14.91	34.59	25.69	0.115	1.594
75	14.91	34.58	25.69	0.174	1.535
100	14.90	34.58	25.69	0.232	1.477
150	14.87	34.59	25.70	0.349	1.360
200	14.11	34.51	25.80	0.464	1.245
250	13.41	34.46	25.91	0.575	1.134
300	12.73	34.42	26.02	0.681	1.028
400	11.28	34.34	26.23	0.879	0.830
500	09.60	34.18	26.40	1.060	0.649
600	07.60	34.06	26.62	1.224	0.485
700	05.87	33.98	26.79	1.368	0.341
800	04.80	34.05	26.97	1.495	0.214
1000	03.90	34.22	27.20	1.709	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 33

M/V *Hugh M. Smith*: Cruise 27, 36°49'N., 173°18'W., February 6, 1955. Messenger time: 2035 GCT. Weather: 02, cloud coverage 2. Wind: 080°, 20 kt. Sea: 3-5 ft. Wire angle: 20°. BT slide: 114

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	11.91	34.33	26.11	6.09 *	0.54
56	11.90	34.31	26.09	6.07	0.54
112	11.86	34.33	26.11	6.03	0.55
168	11.80	34.31	26.11	5.88	0.58
224	10.37	34.27	26.34	5.07	0.97
279	09.48	34.20	26.43	5.30	1.10
335	08.50	34.09	26.50	5.23	1.30
452	06.68	34.02	26.71	4.21	1.68
565	05.40	33.98	26.84	3.23	2.11
675	04.47	34.09	27.04	2.04	2.45
894	03.68	34.25	27.24	0.96	2.72
1112	03.08	34.36	27.39	0.59	2.88
1112	03.02	34.36	27.39	-	-
1319	02.74	34.45	27.49	0.55	2.91

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	11.91	34.33	26.11	0.000	1.377
10	11.91	34.33	26.11	0.019	1.358
20	11.91	34.32	26.10	0.038	1.339
30	11.90	34.32	26.10	0.058	1.319
50	11.90	34.31	26.09	0.096	1.281
75	11.88	34.32	26.10	0.145	1.232
100	11.87	34.33	26.11	0.193	1.184
150	11.81	34.32	26.12	0.290	1.087
200	10.78	34.28	26.27	0.384	0.993
250	09.94	34.24	26.39	0.471	0.906
300	09.07	34.14	26.45	0.555	0.822
400	07.40	34.04	26.63	0.711	0.666
500	06.08	33.99	26.77	0.852	0.525
600	05.07	34.00	26.90	0.982	0.395
700	04.34	34.12	27.07	1.096	0.281
800	03.94	34.20	27.18	1.198	0.179
1000	03.35	34.32	27.33	1.377	0.000

*** Estimated burette reading.**

Table 4.--Oceanographic station data (cont'd)

STATION 34

M/V *Hugh M. Smith*: Cruise 27, 35°17'N., 173°27'W., February 7, 1955. Messenger time: 0738 GCT. Weather: 02, cloud coverage 7. Wind: 140°, 19 kt. Sea: 5-8 ft. Wire angle: 22°. BT slide: 117

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σt	O_2 (ml/l)	PO_4-P (µg at/l)
0	14.21	34.47	25.75	5.89	0.31
54	14.22	34.49	25.77	5.86	0.32
108	13.63	34.40	25.82	5.69	0.45
161	13.10	34.40	25.93	5.39	0.60
215	12.34	34.38	26.06	5.32	0.72
268	11.65	34.33	26.15	5.22	0.88
324	10.78	34.29	26.28	5.28	0.94
437	09.85 Q	NG	NG	NG	NG
546	07.50	34.04	26.61	4.69	1.55
654	05.68	33.98	26.81	3.50	2.06
865	04.29	34.18	27.13	1.64	2.63
1080	03.46	34.33	27.33	0.81	2.85
1080	03.40	34.33	27.33	-	-
1283	03.04	34.40	27.43	0.37	2.96

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σt	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	14.21	34.47	25.75	0.000	1.590
10	14.21	34.47	25.75	0.023	1.567
20	14.22	34.48	25.76	0.045	1.545
30	14.22	34.49	25.77	0.068	1.522
50	14.22	34.49	25.77	0.113	1.477
75	14.19	34.49	25.77	0.169	1.421
100	13.77	34.41	25.80	0.225	1.365
150	13.20	34.40	25.91	0.334	1.256
200	12.53	34.38	26.02	0.439	1.151
250	11.90	34.35	26.12	0.539	1.051
300	11.13	34.30	26.23	0.635	0.955
400	10.14	34.24	26.36	0.816	0.774
500	08.59	34.12	26.51	0.985	0.605
600	06.45	33.98	26.71	1.137	0.453
700	05.28	34.01	26.88	1.272	0.318
800	04.60	34.12	27.04	1.390	0.200
1000	03.72	34.28	27.26	1.590	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 36

M/V *Hugh M. Smith*: Cruise 27, 34°06'N., 173°12'W., February 7, 1955. Messenger time: 1829 GCT. Weather: 02, cloud coverage 8. Wind: 180°, 19 kt. Sea: 3-5 ft. Wire angle: 10°. BT slide: 120

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	14.65	34.47	25.66	5.71	0.30
57	14.68	34.47	25.65	5.71	0.30
PT	-	-	-	-	-
171	14.64	34.47	25.66	5.39	0.47
228	13.50	34.36	25.81	5.20	0.69
285	12.24	34.42	26.11	5.16	0.84
342	11.04	34.27	26.22	5.09	0.99
462	08.54	34.09	26.50	4.97	1.38
576	06.24	34.02	26.77	3.71	1.97
691	04.98	34.04	26.94	2.56	2.33
914	03.65	34.25	27.25	0.90	2.80
1138	03.18	34.40	27.41	0.69	2.90
1349	02.95	34.42	27.45	0.61	2.91

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	14.65	34.47	25.66	0.000	1.604
10	14.66	34.47	25.66	0.023	1.581
20	14.66	34.47	25.66	0.047	1.557
30	14.67	34.47	25.65	0.070	1.534
50	14.68	34.47	25.65	0.118	1.486
75	14.68	34.47	25.65	0.177	1.427
100	14.68	34.47	25.65	0.236	1.368
150	14.66	34.47	25.66	0.355	1.249
200	13.62	34.36	25.79	0.471	1.133
250	13.22	34.39	25.90	0.582	1.022
300	11.95	34.38	26.14	0.686	0.918
400	09.84	34.17	26.35	0.872	0.732
500	07.67	34.05	26.60	1.037	0.567
600	05.93	34.02	26.81	1.179	0.425
700	04.89	34.04	26.95	1.305	0.299
800	04.16	34.14	27.11	1.416	0.188
1000	03.45	34.31	27.31	1.604	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 38

M/V Hugh M. Smith: Cruise 27, 32°27'N., 173°02'W., February 8, 1955. Messenger time: 0917 GCT. Weather: 01, cloud coverage 8. Wind: 190°, 16 kt. Sea: 5-8 ft. Wire angle: 05°. BT slide: 123

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	16.30	34.65	25.43	5.62	0.27
54	16.30	34.63	25.41	5.55	0.25
106	16.28	34.61	25.40	5.51	0.27
160	15.65	34.58	25.52	5.30	0.40
217	14.68	34.49	25.67	5.51	0.41
273	14.06	34.47	25.78	5.12	0.65
325	13.25	34.43	25.92	5.11	0.74
438	11.08	34.29	26.23	5.03	1.04
544	09.10	34.11	26.43	4.75	1.39
657	07.21	33.98	26.61	4.38	1.75
657	07.15	33.98	26.62	-	-
875	04.16	34.14	27.11	1.48	2.81
1086	03.53	34.29	27.29	0.71	3.07
1086	03.46	34.29	27.30	-	-
1302	03.05	34.45	27.46	0.47	3.09

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	16.30	34.65	25.43	0.000	1.814
10	16.30	34.65	25.43	0.026	1.788
20	16.30	34.64	25.42	0.051	1.763
30	16.30	34.64	25.42	0.077	1.737
50	16.30	34.63	25.41	0.129	1.685
75	16.29	34.62	25.41	0.194	1.620
100	16.28	34.61	25.40	0.259	1.555
150	15.81	34.59	25.49	0.388	1.426
200	14.95	34.51	25.62	0.512	1.302
250	14.30	34.48	25.74	0.631	1.183
300	13.72	34.46	25.85	0.745	1.069
400	11.79	34.33	26.13	0.957	0.857
500	09.87	34.18	26.35	1.145	0.669
600	08.12	34.05	26.53	1.315	0.499
700	06.45	33.97	26.70	1.468	0.346
800	04.95	34.04	26.94	1.601	0.213
1000	03.72	34.24	27.23	1.814	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 39

M/V Hugh M. Smith: Cruise 27, 30°59'N., 172°57'W., February 8, 1955. Messenger time: 2058 GCT. Weather: 02, cloud coverage 8. Wind: 140°, 1-3 kt. Sea: 1-3 ft. Wire angle: 00°. BT slide: 126

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	18.45	35.07	25.23	5.33	0.17
21	18.45	35.05	25.22	5.33	0.17
42	18.46	35.03	25.20	5.32	0.16
84	18.36	35.01	25.21	5.33	0.17
126	16.30	34.63	25.41	5.22	0.37
215	14.46	34.51	25.73	4.76	0.69
320	12.16	34.34	26.07	5.11	0.82
429	10.44	34.22	26.29	5.03	1.13
530	08.28	34.05	26.51	4.74	1.53
644	06.16	33.98	26.75	3.46	2.14
857	04.28	34.13	27.09	1.41	2.89
1063	03.50	34.25	27.26	0.52	3.18
1063	03.43	34.25	27.27	-	-
1274	03.04	34.40	27.42	0.43	3.23

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D\,1000 - \Delta D$ (dyn. m)
00	18.45	35.07	25.23	0.000	1.755
10	18.45	35.06	25.22	0.028	1.727
20	18.45	35.05	25.22	0.055	1.700
30	18.45	35.04	25.21	0.083	1.672
50	18.46	35.03	25.20	0.139	1.616
75	18.42	35.02	25.20	0.208	1.547
100	17.40	34.75	25.25	0.278	1.477
150	15.47	34.58	25.56	0.409	1.346
200	14.81	34.53	25.67	0.531	1.224
250	13.54	34.44	25.87	0.645	1.110
300	12.50	34.36	26.02	0.753	1.002
400	10.97	34.26	26.22	0.951	0.804
500	08.95	34.10	26.44	1.130	0.625
600	06.80	33.99	26.67	1.288	0.467
700	05.52	34.00	26.84	1.426	0.329
800	04.62	34.08	27.01	1.547	0.208
1000	03.69	34.21	27.21	1.755	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 41

M/V *Hugh M. Smith*: Cruise 27, 29°29'N., 172°41'W., February 9, 1955. Messenger time: 0923 GCT. Weather: 02, cloud coverage 2. Wind: 080°, 7-10 kt. Sea: 1-3 ft. Wire angle: 10°. BT slide: 129

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	17.70	34.88	25.27	5.57	0.22
53	16.82	34.60	25.27	5.60	0.21
106	16.39	34.60	25.37	5.50	0.29
159	15.41	34.58	25.58	5.12	0.48
217	14.36	34.47	25.72	5.00	0.64
269	13.44	34.42	25.87	5.17	0.72
323	12.46	34.34	26.01	5.15	0.78
434	10.29	34.20	26.30	4.81	1.17
540	08.50	34.07	26.49	4.40	1.57
650	06.18	34.04	26.80	3.40	2.19
868	04.16	34.16	27.12	1.18	2.98
1078	03.53	34.33	27.32	0.59	3.22
1078	03.48	34.33	27.33	-	-
1292	03.04	34.47	27.48	0.86	3.13

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	17.70	34.88	25.27	0.000	1.748
10	17.68	34.87	25.27	0.027	1.721
20	17.60	34.83	25.26	0.054	1.694
30	17.42	34.75	25.24	0.082	1.666
50	16.87	34.60	25.26	0.137	1.611
75	16.79	34.60	25.28	0.205	1.543
100	16.52	34.60	25.34	0.272	1.476
150	15.62	34.59	25.54	0.402	1.346
200	14.66	34.50	25.68	0.524	1.224
250	13.79	34.44	25.82	0.640	1.108
300	12.94	34.38	25.94	0.750	0.998
400	10.92	34.24	26.22	0.952	0.796
500	09.19	34.11	26.41	1.133	0.615
600	07.21	34.05	26.66	1.293	0.455
700	05.45	34.05	26.89	1.429	0.319
800	04.52	34.11	27.05	1.547	0.201
1000	03.76	34.27	27.25	1.748	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 42

M/V *Hugh M. Smith*: Cruise 27, 28°00'N., 172°34'W., February 9, 1955. Messenger time: 2029 GCT. Weather: 01, cloud coverage 8. Wind: 080°, 11-16 kt. Sea: 3-5 ft. Wire angle: 09°. BT slide: 132

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	20.42	35.34	24.93	5.18	0.14
47	20.44	35.35	24.93	5.10	0.12
94	20.04	35.25	24.96	5.18	0.15
136	17.72	34.83	25.23	5.10	0.27
184	16.28	34.70	25.47	4.91	0.44
231	14.98	34.54	25.64	4.91	0.58
346	12.29	34.36	26.06	4.92	0.94
466	10.35	34.23	26.31	4.84	1.23
581	07.58	34.04	26.61	3.90	1.91
695	05.71	34.00	26.82	2.75	2.45
918	03.94	34.23	27.20	0.76	3.16
1141	03.34	34.36	27.36	0.70	3.18
1141	03.28	34.36	27.37	-	-
1352	02.86	34.47	27.49	1.01	3.16

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	20.42	35.34	24.93	0.000	1.828
10	20.42	35.34	24.93	0.030	1.798
20	20.43	35.34	24.93	0.061	1.767
30	20.43	35.35	24.93	0.091	1.737
50	20.44	35.35	24.93	0.152	1.676
75	20.42	35.34	24.93	0.229	1.599
100	19.85	35.21	24.98	0.305	1.523
150	17.28	34.78	25.30	0.448	1.380
200	15.93	34.66	25.52	0.580	1.248
250	14.55	34.50	25.70	0.703	1.125
300	13.29	34.42	25.90	0.816	1.012
400	11.47	34.31	26.17	1.023	0.805
500	09.45	34.17	26.42	1.206	0.622
600	07.24	34.03	26.64	1.367	0.461
700	05.65	34.01	26.84	1.507	0.321
800	04.65	34.11	27.03	1.628	0.200
1000	03.65	34.29	27.28	1.828	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 44

M/V Hugh M. Smith: Cruise 27, 26°30'N., 171°56'W., February 10, 1955. Messenger time: 1010 GCT. Weather: 02, cloud coverage 3. Wind: 090°, 17-21 kt. Sea: 5-8 ft. Wire angle: 20°. BT slide: 135

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	21.75	35.46	24.65	5.01	0.12
79	21.76	35.48	24.67	5.04	0.12
159	21.76	35.44	24.63	4.96	0.12
187	19.56	35.08	24.96	4.80	0.25
223	17.30	34.85	25.34	4.83	0.36
264	15.83	34.67	25.55	4.90	0.47
303	14.62	34.54	25.72	4.88	0.62
408	12.40	34.36	26.04	4.79	0.95
507	10.16	34.20	26.32	4.43	1.39
612	07.41	34.07	26.65	3.37	2.06
818	05.06	34.14	27.01	1.66	2.86
1016	03.97	34.31	27.26	0.96	3.15
1222	03.44	34.38	27.37	0.96	3.13

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D\,1000 - \Delta D$ (dyn. m)
00	21.75	35.46	24.66	0.000	1.985
10	21.75	35.46	24.66	0.033	1.952
20	21.75	35.46	24.66	0.066	1.919
30	21.75	35.46	24.66	0.099	1.886
50	21.76	35.47	24.66	0.165	1.820
75	21.76	35.48	24.67	0.248	1.737
100	21.76	35.46	24.65	0.331	1.654
150	21.76	35.44	24.64	0.498	1.487
200	18.58	34.98	25.13	0.655	1.330
250	16.24	34.70	25.48	0.793	1.192
300	14.75	34.55	25.70	0.917	1.068
400	12.56	34.38	26.02	1.141	0.844
500	10.32	34.21	26.30	1.338	0.647
600	07.67	34.08	26.62	1.506	0.479
700	06.22	34.06	26.80	1.650	0.335
800	05.21	34.13	26.98	1.775	0.210
1000	04.03	34.30	27.25	1.985	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 45

M/V Hugh M. Smith: Cruise 27, 28°00'N., 168°42'W., February 12, 1955. Messenger time: 1110 GCT. Weather: 01, cloud coverage 3. Wind: 050°, 17-21 kt. Sea: 5-8 ft. Wire angle: 20°. BT slide: 142

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	19.92	35.26	25.00	5.13	0.23
65	19.94	35.28	25.01	5.21	0.16
129	17.60	34.87	25.29	4.95	0.32
174	15.74	34.63	25.54	4.91	0.48
218	14.92	34.56	25.67	4.84	0.56
263	13.96	34.49	25.82	4.84	0.68
329	12.60	34.40	26.03	4.88	0.83
444	09.89	34.18	26.35	4.67	1.28
553	07.40	34.07	26.65	3.63	1.97
662	05.92	34.04	26.83	2.43	2.56
877	04.10	34.20	27.16	0.75	3.21
1092	03.50	34.33	27.32	0.47	3.39
1298	03.02	34.45	27.46	0.71	3.13

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	19.92	35.26	25.00	0.000	1.768
10	19.92	35.26	25.00	0.030	1.738
20	19.92	35.27	25.01	0.059	1.709
30	19.92	35.27	25.01	0.089	1.679
50	19.93	35.28	25.01	0.148	1.620
75	19.94	35.28	25.01	0.223	1.545
100	19.87	35.28	25.03	0.297	1.471
150	16.62	34.74	25.42	0.437	1.331
200	15.25	34.59	25.62	0.563	1.205
250	14.24	34.51	25.78	0.682	1.086
300	13.20	34.44	25.94	0.793	0.975
400	10.78	34.25	26.25	0.994	0.774
500	08.60	34.12	26.51	1.168	0.600
600	06.68	34.05	26.74	1.319	0.449
700	05.47	34.05	26.89	1.452	0.316
800	04.55	34.13	27.06	1.569	0.199
1000	03.72	34.28	27.26	1.768	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 46

M/V *Hugh M. Smith*: Cruise 27, 29°30'N., 166°41'W., February 13, 1955. Messenger time: 0617 GCT. Weather: 02, cloud coverage 2. Wind: 060°, 17-21 kt. Sea: 5-8 ft. Wire angle: 26°. BT slide: 147

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	19.53	35.30	25.13	5.27	0.15
74	19.48	35.30	25.14	5.24	0.16
147	19.40	35.26	25.13	5.23	0.16
175	19.40	35.28	25.15	5.22	0.12
207	17.98	34.90	25.22	5.33	0.14
244	16.29	34.72	25.49	4.88	0.42
280	14.42	34.52	25.74	4.86	0.63
379	12.76	34.38	25.98	5.20	0.78
472	10.86	34.27	26.25	5.19	1.05
570	08.72	34.11	26.48	4.67	1.51
763	05.44	34.09	26.92	2.28	2.61
954	04.13	34.25	27.20	0.73	3.15
954	04.05	34.25	27.21	-	-
1154	03.53	34.38	27.36	0.43	3.21

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	19.53	35.30	25.13	0.000	1.898
10	19.53	35.30	25.13	0.028	1.870
20	19.53	35.30	25.13	0.057	1.841
30	19.52	35.30	25.13	0.085	1.813
50	19.50	35.30	25.14	0.142	1.756
75	19.48	35.30	25.15	0.214	1.684
100	19.46	35.26	25.12	0.285	1.613
150	19.40	35.25	25.13	0.430	1.468
200	18.46	34.99	25.17	0.574	1.324
250	16.01	34.68	25.52	0.710	1.188
300	14.02	34.49	25.81	0.831	1.067
400	12.39	34.37	26.04	1.048	0.850
500	10.35	34.22	26.30	1.244	0.654
600	08.08	34.09	26.57	1.414	0.484
700	06.30	34.05	26.79	1.561	0.337
800	05.06	34.12	26.99	1.688	0.210
1000	03.95	34.28	27.24	1.898	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 48

M/V *Hugh M. Smith*: Cruise 27, 30°57'N., 166°49'W., February 13, 1955. Messenger time: 1933 GCT. Weather: 02, cloud coverage 4. Wind: 090°, 7-10 kt. Sea: 3-5 ft. Wire angle: 05°. BT slide: 150

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	19.40	35.32	25.18	5.24	0.20
53	18.92	35.21	25.22	5.33	0.18
105	16.95	34.85	25.43	5.49	0.21
160	16.20	34.67	25.47	5.30	0.31
218	14.38	34.61	25.82	5.00	0.62
271	13.32	34.45	25.92	5.15	0.73
324	12.53	34.40	26.04	5.16	0.76
434	10.38	34.25	26.32	5.26	1.05
434	10.44	34.25	26.31	-	-
541	08.69	34.11	26.49	4.39	1.53
652	06.58	34.04	26.74	3.42	2.08
868	04.52	34.13	27.06	1.28	2.89
1079	03.66	34.34	27.32	0.41	3.21
1079	03.61	34.34	27.32	-	-
1295	03.19	34.47	27.47	0.59	3.16

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	19.40	35.32	25.18	0.000	1.769
10	19.32	35.30	25.19	0.028	1.741
20	19.22	35.28	25.20	0.056	1.713
30	19.13	35.26	25.21	0.084	1.685
50	18.96	35.22	25.22	0.139	1.630
75	18.15	35.08	25.31	0.208	1.561
100	17.07	34.87	25.42	0.274	1.495
150	16.54	34.69	25.40	0.405	1.364
200	14.78	34.63	25.75	0.528	1.241
250	13.73	34.51	25.88	0.641	1.128
300	12.86	34.42	25.99	0.748	1.021
400	10.99	34.29	26.24	0.947	0.822
500	09.38	34.15	26.41	1.127	0.642
600	07.54	34.06	26.62	1.289	0.480
700	06.00	34.05	26.82	1.431	0.338
800	04.98	34.08	26.97	1.556	0.213
1000	03.97	34.25	27.22	1.769	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 50

M/V Hugh M. Smith: Cruise 27, $32^{\circ}23'$N., $166^{\circ}39'$W., February 14, 1955. Messenger time: 0810 GCT. Weather: 02, cloud coverage 6. Wind: 090°, 7-10 kt. Sea: 3-5 ft. Wire angle: 14°. BT slide: 153

OBSERVED

DEPTH (m)	T ($^{\circ}$C)	S ($^{\circ}$/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	15.73	34.58	25.50	5.87	0.20
42	15.74	34.61	25.53	5.79	0.18
83	15.70	34.60	25.53	5.75	0.19
124	14.39	34.70	25.89	5.63	0.43
165	13.45	34.49	25.92	5.35	0.59
211	12.65	34.45	26.05	5.30	0.73
314	11.28	34.25	26.16	5.42	0.91
423	09.95	34.16	26.32	5.15	1.18
423	10.00	34.16	26.32	-	-
525	07.98	34.04	26.54	4.38	1.70
634	06.16	33.96	26.73	3.41	2.17
845	04.24	34.11	27.07	1.24	2.96
1050	03.52	34.27	27.27	0.45	3.19
1050	03.45	34.27	27.28	-	-
1259	03.08	34.42	27.44	0.35	3.18

INTERPOLATED AND CALCULATED

DEPTH (m)	T ($^{\circ}$C)	S ($^{\circ}$/oo)	σ_t	ΔD (dyn. m)	$\Delta D\,1000 - \Delta D$ (dyn. m)
00	15.73	34.58	25.50	0.000	1.649
10	15.73	34.58	25.50	0.025	1.624
20	15.73	34.59	25.51	0.050	1.599
30	15.74	34.60	25.52	0.075	1.574
50	15.74	34.61	25.53	0.124	1.525
75	15.72	34.60	25.52	0.186	1.463
100	15.22	34.65	25.67	0.247	1.402
150	13.79	34.54	25.89	0.360	1.289
200	12.86	34.46	26.02	0.465	1.184
250	12.30	34.40	26.09	0.566	1.083
300	11.54	34.27	26.13	0.665	0.984
400	10.21	34.18	26.30	0.854	0.795
500	08.47	34.07	26.49	1.027	0.622
600	06.65	33.97	26.68	1.182	0.467
700	05.48	33.97	26.83	1.320	0.329
800	04.57	34.07	27.01	1.443	0.206
1000	03.64	34.23	27.23	1.649	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 51

M/V Hugh M. Smith: Cruise 27, 34°23'N., 166°36'W., February 14, 1955. Messenger time: 2055 GCT. Weather: 02, cloud coverage 8. Wind: 160°, 7-10 kt. Sea: 1-3 ft. Wire angle: 15°. BT slide: 156

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σt	O_2 (ml/l)	PO_4-P (µg at/l)
0	13.98	34.43	25.77	5.89	0.38
50	13.67	34.40	25.81	5.71	0.48
101	13.22	34.42	25.92	5.34	0.67
152	12.74	34.38	25.98	5.25	0.76
208	12.17	34.34	26.06	5.26	0.84
259	11.54	34.29	26.14	5.25	0.94
309	10.77	34.23	26.24	5.18	1.06
416	09.26	34.11	26.40	5.14	1.34
517	07.50	33.98	26.56	4.37	1.83
624	05.72	33.96	26.79	3.08	2.41
831	04.18	34.16	27.12	1.24	3.08
1035	03.47	34.33	27.33	0.43	3.36
1242	02.97	34.42	27.45	0.34	3.39

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σt	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	13.98	34.43	25.77	0.000	1.555
10	13.95	34.42	25.77	0.022	1.533
20	13.93	34.42	25.77	0.045	1.510
30	13.89	34.41	25.77	0.067	1.488
50	13.67	34.40	25.81	0.112	1.443
75	13.45	34.41	25.86	0.166	1.389
100	13.25	34.42	25.91	0.220	1.335
150	12.78	34.38	25.98	0.325	1.230
200	12.23	34.34	26.05	0.427	1.128
250	11.63	34.29	26.13	0.527	1.028
300	10.90	34.25	26.23	0.622	0.933
400	09.54	34.13	26.37	0.802	0.753
500	07.85	34.00	26.53	0.969	0.586
600	06.06	33.96	26.75	1.118	0.437
700	05.02	34.02	26.92	1.248	0.307
800	04.34	34.13	27.08	1.363	0.192
1000	03.60	34.31	27.30	1.555	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 52

M/V *Hugh M. Smith*: Cruise 27, 35°31'N., 166°42'W., February 15, 1955. Messenger time: 0613 GCT. Weather: 02, cloud coverage 8. Wind: 180°, 10 kt. Sea: 1-3 ft. Wire angle: 12°. BT slide: 158

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	12.91	34.31	25.90	6.79	0.47
52	12.78	34.31	25.92	6.00	0.50
105	12.68	34.33	25.96	5.91	0.60
157	12.16	34.34	26.07	5.35	0.82
215	11.23	34.31	26.22	5.28	1.04
267	10.66	34.25	26.27	5.33	1.12
320	09.77	34.18	26.37	5.21	1.29
430	08.37	34.07	26.51	5.03	1.60
534	06.65	33.98	26.68	4.05	2.16
646	05.16	34.00	26.89	2.59	2.75
PT	-	-	-	-	-
1067	03.62	34.34	27.32	0.39	3.42
1067	03.55	34.34	27.33	-	-
1277	02.97	34.47	27.49	0.25	3.50

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	12.91	34.31	25.90	0.000	1.497
10	12.87	34.31	25.90	0.021	1.476
20	12.83	34.31	25.91	0.042	1.455
30	12.80	34.31	25.92	0.063	1.434
50	12.77	34.31	25.92	0.105	1.392
75	12.72	34.32	25.94	0.158	1.339
100	12.70	34.33	25.95	0.210	1.287
150	12.25	34.34	26.05	0.312	1.185
200	11.50	34.32	26.17	0.410	1.087
250	10.86	34.28	26.26	0.503	0.994
300	10.06	34.21	26.35	0.592	0.905
400	08.74	34.10	26.48	0.762	0.735
500	07.30	34.01	26.62	0.919	0.578
600	05.78	33.97	26.79	1.061	0.436
700	04.80	34.05	26.97	1.187	0.310
800	04.35	34.14	27.09	1.299	0.198
1000	03.84	34.29	27.26	1.497	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 54

M/V Hugh M. Smith: Cruise 27, 37°00'N., 166°43'W., February 15, 1955. Messenger time: 1831 GCT. Weather: 50, cloud coverage 9. Wind: 220°, 22-27 kt. Sea: 5-8 ft. Wire angle: 35°. BT slide: 161

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	12.67	34.33	25.96	5.98	0.55
47	12.41	34.31	25.99	6.06 *	0.56
95	12.41	34.29	25.98	6.00	0.62
142	12.41	34.29	25.98	5.96	0.56
190	12.20	34.31	26.04	5.71	0.72
238	11.68	34.31	26.13	5.38	0.92
285	10.94	34.23	26.21	5.35	0.99
387	09.52	34.18	26.41	5.25	1.25
485	07.70	34.02	26.57	4.86	1.65
583	06.12	33.96	26.74	3.74	2.22
775	04.40	34.07	27.03	1.69	3.00
977	03.68	34.22	27.22	0.79	3.31
977	03.63	34.22	27.22	-	-
1177	03.05	34.38	27.41	0.48	3.40

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	12.67	34.33	25.96	0.000	1.527
10	12.67	34.33	25.96	0.021	1.506
20	12.67	34.33	25.96	0.041	1.486
30	12.67	34.32	25.95	0.062	1.465
50	12.42	34.31	25.99	0.103	1.424
75	12.41	34.30	25.99	0.154	1.373
100	12.41	34.29	25.98	0.205	1.322
150	12.39	34.29	25.98	0.309	1.218
200	12.10	34.31	26.05	0.411	1.116
250	11.51	34.29	26.15	0.509	1.018
300	10.78	34.23	26.24	0.604	0.923
400	09.28	34.16	26.44	0.781	0.746
500	07.48	34.01	26.59	0.942	0.585
600	05.88	33.96	26.77	1.086	0.441
700	04.79	34.02	26.94	1.214	0.313
800	04.24	34.10	27.07	1.327	0.200
1000	03.60	34.22	27.23	1.527	0.000

* Estimated burette reading.

Table 4.--Oceanographic station data (cont'd)

STATION 56

M/V Hugh M. Smith: Cruise 27, 37°08'N., 164°09'W., February 16, 1955. Messenger time: 0845 GCT. Weather: 01, cloud coverage 8. Wind: 290°, 11-16 kt. Sea: 5-8 ft. Wire angle: 26°. BT slide: 164

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	12.32	34.29	26.00	6.22 *	0.53
52	12.19	34.23	25.98	6.03 *	0.57
PT	-	-	-	-	-
157	11.64	34.23	26.08	5.88	0.71
210	11.14	34.18	26.13	5.95	0.76
262	10.88	34.23	26.22	5.48	0.97
316	09.94	34.16	26.32	5.53	1.07
426	08.33	34.05	26.50	5.15	1.45
532	06.60	33.98	26.69	3.97	1.99
639	05.20	33.98	26.87	2.73	2.44
847	04.04	34.18	27.15	1.20	2.94
1058	03.37	34.31	27.32	0.49	3.16
1058	03.31	34.31	27.33	-	-
1260	02.92	34.42	27.45	0.33	3.24

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	12.32	34.29	26.00	0.000	1.485
10	12.28	34.26	25.98	0.020	1.465
20	12.25	34.24	25.97	0.041	1.444
30	12.21	34.23	25.97	0.061	1.424
50	12.19	34.23	25.97	0.102	1.383
75	12.14	34.22	25.98	0.154	1.331
100	11.82	34.22	26.04	0.204	1.281
150	11.67	34.22	26.07	0.304	1.181
200	11.24	34.19	26.12	0.403	1.082
250	10.97	34.22	26.19	0.498	0.987
300	10.23	34.18	26.29	0.591	0.894
400	08.70	34.07	26.46	0.763	0.722
500	07.14	34.00	26.63	0.921	0.564
600	05.63	33.96	26.80	1.062	0.423
700	04.68	34.06	26.99	1.185	0.300
800	04.20	34.15	27.11	1.294	0.191
1000	03.50	34.28	27.29	1.485	0.000

* Estimated burette reading.

Table 4.--Oceanographic station data (cont'd)

STATION 57

M/V Hugh M. Smith: Cruise 27, 37°00'N., 162°16'W., February 16, 1955. Messenger time: 1924 GCT. Weather: 02, cloud coverage 3. Wind: 300°, 17-21 kt. Sea: 3-5 ft. Wire angle: 30°. BT slide: 167

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	11.34	34.16	26.08	6.25 *	0.65
46	11.26	34.16	26.09	6.15 *	0.66
92	11.20	34.14	26.09	6.16 *	0.67
139	11.04	34.14	26.12	6.21 *	0.69
190	10.96	34.13	26.13	5.48	0.72
236	10.50	34.22	26.27	5.45	1.06
283	09.94	34.18	26.34	5.30	1.12
382	08.71	34.07	26.46	4.39	1.37
474	07.24	33.98	26.60	3.35	1.86
576	05.86	33.96	26.77	1.60	2.30
769	04.39	34.07	27.03	0.81	2.94
962	03.69	34.20	27.20	0.41	3.27
1166	03.15	34.34	27.37	NS	3.35

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	11.34	34.16	26.08	0.000	1.472
10	11.32	34.16	26.08	0.019	1.453
20	11.29	34.16	26.09	0.039	1.433
30	11.27	34.16	26.09	0.058	1.414
50	11.24	34.15	26.09	0.097	1.375
75	11.22	34.14	26.09	0.146	1.326
100	11.18	34.14	26.09	0.194	1.278
150	11.01	34.13	26.12	0.292	1.180
200	10.94	34.13	26.13	0.388	1.084
250	10.35	34.21	26.30	0.482	0.990
300	09.79	34.17	26.36	0.570	0.902
400	08.52	34.06	26.48	0.738	0.734
500	06.87	33.97	26.65	0.894	0.578
600	05.62	33.97	26.81	1.033	0.439
700	04.80	34.02	26.94	1.159	0.313
800	04.22	34.10	27.07	1.272	0.200
1000	03.62	34.22	27.23	1.472	0.000

* Estimated burette reading.

Table 4.--Oceanographic station data (cont'd)

STATION 59

M/V Hugh M. Smith: Cruise 27, 36°57'N., 160°05'W., February 17, 1955. Messenger time: 0817 GCT. Weather: 02, cloud coverage 3. Wind: 330°, 30 kt. Sea: 5-8 ft. Wire angle: 36°. BT slide: 170

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	12.86	34.22	25.84	5.94	0.42
50	12.86	34.22	25.84	5.93	0.43
NG	-	-	-	-	-
150	12.54	34.14	25.84	6.08 *	0.54
NG	-	-	-	-	-
250	11.48	34.27	26.14	5.39	0.90
302	10.81	34.20	26.21	5.28	0.95
407	09.10	34.05	26.38	5.24	1.16
510	07.38	34.02	26.62	4.38	1.65
612	05.83	33.98	26.79	3.26	2.13
811	04.30	34.11	27.07	1.42	2.67
1017	03.53	34.25	27.26	0.55	3.01
1219	03.05	34.36	27.39	0.27	3.07

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	12.86	34.22	25.84	0.000	1.564
10	12.86	34.22	25.84	0.022	1.542
20	12.86	34.22	25.84	0.043	1.521
30	12.86	34.22	25.84	0.065	1.499
50	12.86	34.22	25.84	0.109	1.455
75	12.85	34.21	25.83	0.164	1.400
100	12.76	34.19	25.83	0.219	1.345
150	12.54	34.14	25.84	0.329	1.235
200	12.01	34.21	25.99	0.436	1.128
250	11.48	34.27	26.14	0.536	1.028
300	10.81	34.20	26.21	0.632	0.932
400	09.18	34.06	26.37	0.813	0.751
500	07.58	34.02	26.59	0.977	0.587
600	05.98	33.98	26.77	1.122	0.442
700	04.92	34.03	26.94	1.250	0.314
800	04.38	34.10	27.05	1.364	0.200
1000	03.58	34.25	27.25	1.564	0.000

* Estimated burette reading.

Table 4.--Oceanographic station data (cont'd)

STATION 60

M/V Hugh M. Smith: Cruise 27, 35°28'N., 159°53'W., February 17, 1955. Messenger time: 1919 GCT. Weather: 02, cloud coverage 2. Wind: 040°, 4-6 kt. Sea: 3-5 ft. Wire angle: 20°. BT slide: 173

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	12.87	34.31	25.90	6.06 *	0.41
50	12.84	34.27	25.88	5.99 *	0.42
100	12.79	34.27	25.89	5.88	0.45
149	12.21	34.16	25.92	5.99	0.49
204	11.99	34.23	26.02	5.40	0.73
254	11.20	34.23	26.16	5.42	0.87
304	10.66	34.23	26.26	5.41	0.97
410	09.10	34.09	26.41	4.96	1.27
509	07.68	34.02	26.57	4.50	1.61
614	05.81	34.00	26.81	3.11	2.18
819	04.22	34.14	27.10	1.27	2.80
1019	03.54	34.25	27.25	0.65	3.05
1019	03.49	34.25	27.26	-	-
1224	03.02	34.36	27.39	0.28	3.09

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	12.87	34.31	25.90	0.000	1.547
10	12.86	34.30	25.90	0.021	1.526
20	12.86	34.29	25.89	0.042	1.505
30	12.85	34.28	25.88	0.064	1.483
50	12.84	34.27	25.88	0.106	1.441
75	12.84	34.27	25.88	0.160	1.387
100	12.79	34.27	25.89	0.214	1.333
150	12.22	34.16	25.91	0.321	1.226
200	12.06	34.23	26.00	0.426	1.121
250	11.32	34.23	26.14	0.526	1.021
300	10.71	34.23	26.25	0.621	0.926
400	09.25	34.10	26.39	0.799	0.748
500	07.84	34.02	26.55	0.964	0.583
600	06.12	34.00	26.77	1.111	0.436
700	05.00	34.06	26.95	1.238	0.309
800	04.33	34.13	27.08	1.351	0.196
1000	03.53	34.25	27.26	1.547	0.000

* Estimated burette reading.

Table 4.--Oceanographic station data (cont'd)

STATION 61

M/V Hugh M. Smith: Cruise 27, 34°00'N., 159°42'W., February 18, 1955. Messenger time: 0536 GCT. Weather: 02, cloud coverage 1. Wind: 140°, 4-6 kt. Sea: 3-5 ft. Wire angle: 07°. BT slide: 176

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	14.03	34.31	25.66	5.95 *	0.32
85	13.80	34.34	25.73	5.55	0.46
128	12.89	34.34	25.92	5.18	0.70
160	12.48	34.33	26.00	5.25	0.74
219	11.69	34.29	26.12	5.35	0.82
272	11.10	34.22	26.17	5.32	0.93
326	10.43	34.22	26.29	5.21	1.01
438	09.08	34.14	26.46	4.92	1.32
545	06.70	34.00	26.69	3.78	1.94
656	05.23	33.98	26.86	2.67	2.36
874	03.95	34.18	27.16	0.87	2.94
1083	03.34	34.33	27.34	0.28	3.16
1083	03.28	34.33	27.35	-	-
1296	02.98	34.42	27.45	0.35	NG

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	14.03	34.31	25.67	0.000	1.556
10	13.85	34.34	25.73	0.023	1.533
20	13.80	34.34	25.74	0.046	1.510
30	13.80	34.34	25.74	0.069	1.487
50	13.80	34.34	25.74	0.114	1.442
75	13.80	34.34	25.74	0.171	1.385
100	13.38	34.34	25.82	0.227	1.329
150	12.61	34.34	25.98	0.334	1.222
200	11.95	34.30	26.07	0.436	1.120
250	11.33	34.25	26.15	0.534	1.022
300	10.75	34.22	26.23	0.629	0.927
400	09.60	34.17	26.39	0.808	0.748
500	07.81	34.06	26.59	0.971	0.585
600	05.87	33.98	26.79	1.116	0.440
700	04.90	34.00	26.92	1.244	0.312
800	04.27	34.10	27.06	1.359	0.197
1000	03.57	34.26	27.26	1.556	0.000

* Estimated burette reading.

Table 4.--Oceanographic station data (cont'd)

STATION 63

M/V Hugh M. Smith: Cruise 27, 32°27'N., 159°30'W., February 18, 1955. Messenger time: 1720 GCT. Weather: 02, cloud coverage 1. Wind: 140°, 4-6 kt. Sea: 3-5 ft. Wire angle: 20°. BT slide: 179

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	16.02	34.58	25.44	5.59	0.20
49	16.01	34.58	25.45	5.57	0.21
98	16.00	34.56	25.43	5.54	0.22
148	14.54	34.45	25.67	5.29	0.48
202	13.29	34.33	25.83	5.13	0.66
252	12.52	34.33	25.99	5.18	0.80
302	11.90	34.29	26.08	5.23	0.82
406	10.46	34.16	26.24	5.06	1.08
505	08.70	34.05	26.44	4.49	1.51
609	06.69	33.91	26.62	3.64	2.00
609	06.64	33.91	26.63	-	-
813	04.50	34.05	27.00	1.42	2.89
1013	03.64	34.23	27.23	0.43	3.21
1013	03.58	34.23	27.24	-	-
1218	03.08	34.38	27.40	0.31	3.23

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	16.02	34.58	25.44	0.000	1.722
10	16.01	34.58	25.44	0.025	1.697
20	16.01	34.58	25.44	0.051	1.671
30	16.01	34.58	25.44	0.077	1.645
50	16.01	34.58	25.44	0.128	1.594
75	16.02	34.57	25.43	0.192	1.530
100	15.98	34.56	25.43	0.257	1.465
150	14.52	34.45	25.67	0.380	1.342
200	13.40	34.34	25.82	0.496	1.226
250	12.55	34.33	25.98	0.604	1.118
300	11.92	34.30	26.08	0.707	1.015
400	10.58	34.18	26.23	0.901	0.821
500	08.81	34.06	26.43	1.080	0.642
600	06.85	33.92	26.61	1.241	0.481
700	05.60	33.95	26.79	1.385	0.337
800	04.60	34.04	26.98	1.510	0.212
1000	03.66	34.22	27.22	1.722	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 64

M/V *Hugh M. Smith*: Cruise 27, 30°59'N., 159°22'W., February 19, 1955. Messenger time: 0315 GCT. Weather: 02, cloud coverage 4. Wind: 070°, 4-6 kt. Sea: 1-3 ft. Wire angle: 06°. BT slide: 182

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	17.16	34.78	25.33	5.52	0.19
43	17.15	34.79	25.33	5.46	0.18
85	16.74	34.70	25.36	5.49	0.21
127	14.70	34.47	25.65	5.18	0.47
171	13.63	34.47 P	25.87 P	5.09	0.60
217	12.74	34.33	25.94	5.09	0.75
324	11.26	34.29	26.20	5.21	0.85
435	09.64	34.14	26.36	4.68	1.21
435	09.71	34.14	26.34	-	-
541	07.78	34.05	26.58	4.13	1.61
652	05.68	33.96	26.79	2.65	2.24
870	04.20	34.18	27.14	0.76	2.87
1080	03.57	34.34	27.32	0.32	3.05
1080	03.51	34.34	27.33	-	-
1295	03.13	34.43	27.44	0.44	3.00

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D\,1000 - \Delta D$ (dyn. m)
00	17.16	34.78	25.33	0.000	1.674
10	17.16	34.78	25.33	0.027	1.647
20	17.16	34.78	25.33	0.053	1.621
30	17.16	34.78	25.33	0.080	1.594
50	17.05	34.76	25.34	0.133	1.541
75	16.80	34.71	25.36	0.200	1.474
100	16.58	34.67	25.38	0.266	1.408
150	14.20	34.43	25.72	0.390	1.284
200	13.07	34.35	25.89	0.502	1.172
250	12.21	34.30	26.03	0.607	1.067
300	11.54	34.28	26.14	0.708	0.966
400	10.16	34.17	26.30	0.896	0.778
500	08.52	34.08	26.49	1.069	0.605
600	06.60	33.98	26.69	1.223	0.451
700	05.21	34.00	26.88	1.358	0.316
800	04.52	34.11	27.05	1.476	0.198
1000	03.74	34.30	27.28	1.674	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 66

M/V *Hugh M. Smith*: Cruise 27, 29°28'N., 159°12'W., February 19, 1955. Messenger time: 1501 GCT. Weather: 02, cloud coverage 2. Wind: 120°, 11-16 kt. Sea: 3-5 ft. Wire angle: 10°. BT slide: 185

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	18.95	35.19	25.20	5.24	0.17
85	18.40	35.07	25.24	5.30	0.16
126	15.88	34.58	25.47	5.12	0.34
159	14.80	34.51	25.66	5.00	0.49
216	13.38	34.40	25.87	5.01	0.63
268	12.40	34.29	25.98	5.02	0.79
321	11.55	34.29	26.14	4.98	0.89
430	09.91	34.18	26.34	4.69	1.20
534	07.70	34.05	26.59	3.89	1.72
644	05.76	34.02	26.84	2.43	2.32
856	04.30	34.18	27.12	0.74	2.93
1062	03.66	34.34	27.32	0.36	3.11
1273	03.23	34.49	27.48	0.72	2.98

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	18.95	35.19	25.20	0.000	1.691
10	18.95	35.19	25.20	0.028	1.663
20	18.94	35.18	25.19	0.056	1.635
30	18.94	35.18	25.19	0.084	1.607
50	18.80	35.15	25.21	0.139	1.552
75	18.50	35.09	25.24	0.209	1.482
100	17.60	34.88	25.30	0.277	1.414
150	15.08	34.53	25.61	0.406	1.285
200	13.75	34.44	25.83	0.523	1.168
250	12.70	34.32	25.95	0.632	1.059
300	11.87	34.29	26.08	0.735	0.956
400	10.36	34.20	26.29	0.927	0.764
500	08.49	34.09	26.51	1.100	0.591
600	06.20	34.02	26.78	1.249	0.442
700	05.18	34.06	26.93	1.378	0.313
800	04.62	34.13	27.05	1.493	0.198
1000	03.80	34.32	27.29	1.691	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 67

M/V Hugh M. Smith: Cruise 27, 28°00'N., 159°03'W., February 20, 1955. Messenger time: 0204 GCT. Weather: 02, cloud coverage 6. Wind: 070°, 17-21 kt. Sea: 5-8 ft. Wire angle: 20°. BT slide: 188

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	20.91	35.39	24.83	5.12	0.14
57	20.19	35.28	24.94	5.11	0.15
113	19.08	35.05	25.06	5.23	0.17
170	16.00	34.61	25.47	5.05	0.43
226	14.40	34.43	25.68	5.03	0.55
282	13.44	34.36	25.83	4.97	0.71
340	12.04	34.29	26.05	4.99	0.86
458	09.38	34.13	26.39	4.54	1.33
572	07.08	34.13	26.74	3.45	1.95
684	05.54	34.07	26.89	2.02	2.51
904	04.22	34.31	27.24	0.58	3.01
1124	03.54	34.51	27.46	0.63	3.13
1334	03.09	34.49	27.49	1.01	2.93

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	20.91	35.39	24.83	0.000	1.769
10	20.90	35.39	24.84	0.031	1.738
20	20.88	35.39	24.84	0.062	1.707
30	20.88	35.39	24.84	0.094	1.675
50	20.39	35.32	24.92	0.156	1.613
75	19.79	35.20	24.99	0.231	1.538
100	19.39	35.11	25.02	0.306	1.463
150	17.77	34.85	25.23	0.451	1.318
200	14.94	34.48	25.60	0.582	1.187
250	14.00	34.40	25.74	0.701	1.068
300	13.10	34.34	25.88	0.815	0.954
400	10.58	34.20	26.25	1.018	0.751
500	08.43	34.12	26.54	1.191	0.578
600	06.65	34.12	26.79	1.338	0.431
700	05.38	34.08	26.92	1.467	0.302
800	04.65	34.21	27.11	1.580	0.189
1000	03.98	34.39	27.33	1.769	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 69

M/V *Hugh M. Smith*: Cruise 27, 26°30'N., 158°47'W., February 20, 1955. Messenger time: 1424 GCT. Weather: 02, cloud coverage 2. Wind: 070°, 17-21 kt. Sea: 5-8 ft. Wire angle: 25°. BT slide: 191

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
0	21.61	35.43	24.67	5.03	0.13
42	21.60	35.37	24.63	5.01	0.12
84	21.25	35.41	24.75	5.00	0.14
121	19.53	35.12	24.99	4.79	0.26
162	17.75	34.87	25.25	4.66	0.37
207	16.18	34.69	25.49	4.80	0.44
310	12.12	34.18	25.95	4.64	0.84
419	09.75	34.13	26.33	4.57	1.11
419	09.95	34.13	26.30	-	-
523	07.44	34.07	26.64	3.72	1.79
627	06.18	34.00	26.76	2.60	2.27
833	04.44	34.18	27.11	0.75	2.94
1041	03.76	34.42	27.37	0.69	3.08
1243	03.30	34.49	27.47	1.03	2.94

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	21.61	35.43	24.67	0.000	1.808
10	21.61	35.42	24.67	0.033	1.775
20	21.60	35.40	24.65	0.066	1.742
30	21.60	35.38	24.64	0.099	1.709
50	21.52	35.37	24.65	0.165	1.643
75	21.27	35.41	24.75	0.247	1.561
100	21.15	35.40	24.78	0.328	1.480
150	18.35	34.95	25.17	0.480	1.328
200	16.38	34.71	25.46	0.616	1.192
250	13.58	34.33	25.78	0.738	1.070
300	12.27	34.20	25.94	0.849	0.959
400	10.23	34.14	26.26	1.050	0.758
500	07.88	34.09	26.60	1.219	0.589
600	06.46	34.00	26.73	1.366	0.442
700	05.35	34.05	26.90	1.498	0.310
800	04.65	34.14	27.06	1.615	0.193
1000	03.86	34.38	27.33	1.808	0.000

Table 4.--Oceanographic station data (cont'd)

STATION 70

M/V Hugh M. Smith: Cruise 27, 25°00'N., 158°40'W., February 21, 1955. Messenger time: first cast 0155 GCT, second cast 0224 GCT. Weather: 15, cloud coverage 6. Wind: 060°, 17-21 kt. Sea: 8-12 ft. Wire angle: first cast 05°, second cast 06°. BT slide: 194

OBSERVED

	DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (µg at/l)
	0	21.55	35.41	24.67	5.05	0.13
	59	20.94	35.39	24.82	5.08	0.14
	117	19.55	35.12	24.99	4.78	0.23
	175	17.92	34.92	25.25	4.75	0.34
	234	15.26	34.58	25.61	4.62	0.52
	292	12.84	34.45	26.02	4.81	0.79
I	351	11.06	34.33	26.26	4.65	1.01
	471	08.43	34.07	26.50	4.17	1.77
	587	06.31	34.04	26.78	2.68	2.24
	699	04.94	34.13	27.02	1.21	2.83
	384	10.10	34.16	26.30	4.52	1.36
II	624	05.56	34.09	26.91	1.73	2.70
	850	04.41	34.31	27.22	0.90	3.01

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	$\Delta D_{1000} - \Delta D$ (dyn. m)
00	20.95	35.41	-	-	-
10	20.95	35.41	-	-	-
20	20.95	35.40	-	-	-
30	20.96	35.40	-	-	-
50	20.98	35.39	-	-	-
75	20.30	35.26	-	-	-
100	19.85	35.17	-	-	-
150	18.72	35.02	-	-	-
200	17.04	34.77	-	-	-
250	14.58	34.54	-	-	-
300	12.61	34.44	-	-	-
400	09.81	34.14	-	-	-
500	07.93	34.05	-	-	-
600	06.01	34.05	-	-	-
700	04.94	34.13	-	-	-
800	04.60	34.21	-	-	-

Table 4.--Oceanographic station data (cont'd)

STATION 72

M/V Hugh M. Smith: Cruise 27, 23°29'N., 158°27'W., February 21, 1955. Messenger time: 1506 GCT. Weather: 02, cloud coverage 2. Wind: 200°, 4-6 kt. Sea: 1-3 ft. Wire angle: 20°. BT slide: 197

OBSERVED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	O_2 (ml/l)	PO_4-P (μg at/l)
0	22.41	35.21	24.28	5.04	0.24
40	22.39	35.21	24.29	4.88	0.22
79	22.34	35.17	24.27	4.88	0.24
118	22.34	35.21	24.30	4.89	0.24
159	21.64	35.26	24.53	4.69	0.23
203	19.64	35.12	24.96	4.68	0.29
302	14.23	34.42	25.71	4.50	0.71
405	09.88	34.14	26.32	3.81	1.57
505	08.02	34.16	26.63	2.54	2.23
609	06.38	34.20	26.90	1.43	2.64
814	04.60	34.25	27.15	0.79	3.07
1013	03.97	34.43	27.36	1.03	3.16
1013	03.92	34.43	27.36	-	-
1218	03.46	34.52	27.48	1.28	3.06

INTERPOLATED AND CALCULATED

DEPTH (m)	T (°C)	S (°/oo)	σ_t	ΔD (dyn. m)	ΔD 1000 - ΔD (dyn. m)
00	22.41	35.21	24.28	0.000	1.920
10	22.39	35.21	24.29	0.037	1.883
20	22.39	35.21	24.29	0.073	1.847
30	22.39	35.21	24.29	0.110	1.810
50	22.38	35.20	24.28	0.183	1.737
75	22.34	35.17	24.27	0.275	1.645
100	22.34	35.20	24.29	0.367	1.553
150	22.01	35.25	24.42	0.548	1.372
200	19.78	35.13	24.94	0.715	1.205
250	17.99	34.92	25.23	0.863	1.057
300	14.37	34.44	25.70	0.993	0.927
400	10.02	34.15	26.31	1.203	0.717
500	08.08	34.16	26.62	1.369	0.551
600	06.49	34.20	26.88	1.508	0.412
700	05.48	34.21	27.01	1.628	0.292
800	04.66	34.24	27.13	1.736	0.184
1000	03.95	34.42	27.35	1.920	0.000

Table 5.--Summary of observations at bathythermograph lowerings, *Hugh M. Smith* cruise 27, January 5 to February 21, 1955 (For coded values see H. O. Pub 606-C)

Ser. No.	Time, GCT	Date, 1955	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
1	1840	1/6	22°34'N	159°38'W	76.0	130	08	74.5	69.0	1016.4	02	8	3	8	3
2	0200	1/7	22°53'N	160°17'W	75.0	320	06	76.5	70.5	1013.4	03	8	6	7	3
3	0610	1/7	23°10'N	160°51'W	74.1	050	19	74.0	68.5	1014.4	02	8	7	7	3
4	1200	1/7	23°36'N	161°43'W	74.2	090	22	73.0	69.0	1014.4	02	8	8	7	3
5	1805	1/7	23°52'N	162°28'W	74.7	170	15	73.5	67.5	1013.8	02	8	3	9	3
6	2330	1/8	23°52'N	162°30'W	74.7	170	17	75.5	70.5	1014.0	02	8	1	9	3
7	0230	1/8	23°47'N	163°01'W	74.8	170	18	75.5	70.5	1013.6	02	8	2	9	3
8	0630	1/8	23°37'N	163°33'W	74.9	170	15	74.4	70.8	1015.4	02	8	2	9	3
9	1100	1/8	23°31'N	164°07'W	74.7	190	27	71.0	70.0	1016.0	50	8	6	8	3
10	1600	1/8	23°14'N	165°00'W	74.1	140	15	73.6	70.9	1016.1	01	8	3	9	2
11	2300	1/8	22°59'N	165°47'W	75.9	180	12	76.5	72.0	1016.7	03	8	4	9	2
12	0300	1/9	22°49'N	166°21'W	76.3	150	08	76.0	71.0	1016.4	01	3	2	9	2
13	0800	1/9	22°39'N	166°59'W	76.0	180	08	75.1	71.5	1017.9	02	8	3	9	2
14	1138	1/9	22°29'N	167°30'W	75.9	120	18	74.8	71.2	1019.2	02	8	2	9	2
15	1755	1/9	22°22'N	168°09'W	76.1	150	10	75.0	72.0	1017.4	02	8	2	9	3
16	2215	1/9	21°51'N	168°46'W	77.0	180	16	77.1	73.0	1018.1	02	8	3	8	3
17	0255	1/10	21°44'N	169°27'W	76.8	180	11	76.2	72.0	1016.5	18	8	4	8	3
18	0600	1/10	21°38'N	170°20'W	76.9	190	07	76.5	72.5	1017.5	02	8	2	9	3
19	1200	1/10	21°25'N	170°48'W	77.2	210	05	77.0	72.5	1017.6	02	3	1	9	3
20	1545	1/10	21°10'N	171°16'W	77.9	190	07	77.0	72.0	1017.6	01	1	1	9	3
21	1950	1/10	20°55'N	171°46'W	76.4	000	24	75.1	71.0	1020.5	14	0,8	5	8	3
22	2305	1/10	20°39'N	172°17'W	76.2	020	20	74.0	70.0	1019.2	62	0,8	5	8	4
23	0545	1/11	20°33'N	173°01'W	75.2	030	27	74.5	69.5	1020.4	02	4,8	8	7	5
24	0945	1/11	20°27'N	173°32'W	75.1	030	29	74.1	66.1	1021.4	02	8	8	7	5
25	1350	1/11	20°20'N	174°11'W	75.5	050	35	72.5	65.5	1022.0	03	8	8	7	5
26	1800	1/11	20°15'N	174°43'W	76.6	080	32	72.0	64.8	1023.4	02	7	8	7	5-6
27	2200	1/11	20°26'N	175°15'W	76.8	050	30	74.5	64.5	1025.2	02	8	5	9	5-6
28	0130	1/12	20°33'N	175°50'W	76.8	080	31	74.0	65.0	1023.0	01	8	3	9	5
29	0505	1/12	20°37'N	176°20'W	76.5	070	27	73.5	64.5	1023.9	02	8	8	8	5
30	0910	1/12	20°48'N	176°57'W	76.6	080	24	73.0	65.4	1024.0	02	8	3	9	5

Table 5.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 27, January 5 to February 21, 1955 (For coded values see H. O. Pub 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1955	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Baro-meter, mb.	Wea-ther	Clouds		Visi-bili-ty	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
31	1200	1/12	20°53'N	177°13'W	76.8	080	18	73.5	65.0	1023.4	02	8	7	9	4
32	1800	1/12	20°50'N	177°23'W	76.0	070	22	73.5	66.0	1023.9	02	8	3	9	4
33	2330	1/12	21°03'N	177°54'W	77.5	080	18	75.1	66.5	1022.9	02	8	8	8	4
34	0330	1/13	21°15'N	178°26'W	76.5	090	25	75.0	67.5	1022.4	02	8	7	9	4
35	0650	1/13	21°28'N	179°05'W	77.2	080	20	74.8	66.1	1023.3	02	8	5	9	4
36	1015	1/13	21°40'N	179°31'W	77.0	090	13	76.0	68.5	1023.4	02	8	4	9	3
37	1315	1/13	21°51'N	180°00'	76.7	090	20	74.0	66.9	1022.0	02	8	3	9	X
38	1715	1/13	21°56'N	179°33'E	76.5	090	20	75.5	67.5	1023.0	02	8	3	9	3
39	2130	1/13	22°00'N	178°52'E	76.2	090	16	76.1	67.0	1022.7	02	8	7	9	3
40	0155	1/14	22°09'N	178°08'E	77.2	090	12	78.0	68.0	1019.7	02	8	7	9	2
41	0630	1/14	22°31'N	177°30'E	76.4	090	18	75.2	66.5	1020.4	02	6	9	8	3
42	1230	1/14	22°45'N	176°47'E	76.1	070	08	75.1	66.1	1020.4	02	6	9	8	3
43	1615	1/14	22°57'N	176°10'E	75.8	050	11	75.5	66.5	1019.0	02	6	7	8	3
44	2020	1/14	23°08'N	175°21'E	76.4	040	11	75.5	66.5	1020.9	01	6	7	9	3
45	0005	1/15	23°19'N	174°46'E	75.0	080	13	75.0	66.5	1018.0	01	2	1	9	3
46	0550	1/15	23°33'N	174°03'E	76.0	020	09	76.5	67.0	1017.9	02	6	2	9	3
47	1020	1/15	23°49'N	173°30'E	75.0	020	19	71.5	67.4	1019.9	02	6	3	9	5
48	1315	1/15	23°57'N	173°00'E	75.2	260	09	66.5	66.0	1020.0	51	8	9	0	5
49	1630	1/15	23°57'N	172°38'E	76.2	060	30	70.0	65.8	1020.0	03	8	8	3	5
50	2210	1/15	24°03'N	172°09'E	75.9	060	26	73.0	67.0	1023.4	02	8	8	8	5
51	0200	1/16	24°17'N	171°37'E	76.5	030	33	74.0	65.0	1023.0	03	6	7	8	5
52	0600	1/16	24°34'N	171°05'E	76.3	080	31	71.5	63.0	1022.5	01	6	3	9	5
53	1100	1/16	24°50'N	170°31'E	73.0	070	19	71.5	63.0	1024.9	02	6	4	9	4
54	1440	1/16	24°59'N	169°31'E	72.2	080	21	71.1	63.1	1023.4	02	8	3	9	3
55	1930	1/16	25°25'N	169°30'E	71.4	090	26	70.2	64.0	1023.9	01	8	7	9	3
56	2300	1/16	25°56'N	169°28'E	72.0	100	18	73.0	64.0	1025.4	02	4, 8	7	9	3
57	0300	1/17	26°29'N	169°32'E	71.0	100	18	76.0	65.0	1024.0	02	8	1	9	3
58	0755	1/17	27°02'N	169°39'E	70.5	140	14	69.9	62.5	1024.8	02	X	0	9	3
59	1200	1/17	27°30'N	169°49'E	70.1	120	07	70.0	62.2	1025.4	02	X	0	9	3
60	1515	1/17	27°55'N	169°50'E	70.0	130	10	69.0	61.0	1024.7	02	X	0	9	3

Table 5.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 27, January 5 to February 21, 1955 (For coded values see H. O. Pub 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1955	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
61	2115	1/17	28°25'N	169°50'E	70.5	000	05	69.0	62.0	1024.9	02	6	1	9	3
62	0120	1/18	29°00'N	169°53'E	71.5	200	10	69.5	64.7	1022.4	02	6	6	9	3
63	0505	1/18	29°30'N	169°56'E	70.9	250	16	69.4	65.1	1021.8	02	4, 8	5	9	3
64	1030	1/18	30°00'N	170°05'E	68.4	230	14	68.2	65.2	1021.1	02	1	5	9	3
65	1350	1/18	30°33'N	170°22'E	66.0	260	18	67.0	66.0	1020.0	02	X	X	9	4
66	1720	1/18	31°05'N	170°34'E	67.4	270	20	66.4	64.9	1018.0	02	4, 8	5	9	3
67	2215	1/18	31°31'N	170°46'E	65.0	270	15	65.2	62.2	1018.4	02	4, 8	5	9	3
68	0130	1/19	32°00'N	170°37'E	63.4	280	25	65.1	62.5	1016.2	02	4	4	9	3
69	2325	1/19	32°41'N	171°20'E	62.0	330	16	56.1	50.0	1024.4	02	8	3	9	3
70	0405	1/20	32°28'N	171°55'E	64.0	350	16	56.5	51.5	1024.1	02	8	5	9	5
71	1200	1/20	32°08'N	172°50'E	63.9	090	05	58.0	50.0	1026.4	02	X	3	9	4
72	1800	1/20	31°56'N	173°29'E	63.5	190	12	59.0	49.5	1025.0	01	4	4	9	4
73	0000	1/21	31°45'N	174°00'E	65.8	140	15	61.0	53.0	1024.9	02	6	4	9	4
74	0600	1/21	31°37'N	174°35'E	64.5	160	25	62.9	55.6	1021.5	02	8	7	9	4
75	1200	1/21	31°30'N	175°10'E	63.5	190	30	63.5	56.0	1020.4	02	X	4	9	5
76	1800	1/21	31°23'N	175°45'E	65.5	190	33	66.0	61.5	1016.6	01	X	3	9	5
77	0000	1/22	31°15'N	176°20'E	65.8	210	32	68.0	64.0	1014.9	02	6	8	7	5
78	0600	1/22	30°58'N	176°52'E	66.5	240	23	66.8	65.1	1015.5	63	0	9	5	5
79	1200	1/22	30°43'N	177°23'E	66.0	250	04	65.0	63.5	1018.4	51	X	9	7	3
80	1800	1/22	30°26'N	177°54'E	66.0	190	20	67.0	65.0	1018.4	02	X	9	7	3
81	0000	1/23	30°09'N	178°27'E	65.5	200	15	68.0	65.1	1018.8	01	6	8	8	3
82	0600	1/23	29°55'N	178°58'E	66.2	210	20	66.0	65.8	1017.5	46	8	9	1	3
83	1200	1/23	29°42'N	179°28'E	66.0	240	23	67.0	66.1	1018.9	46	X	9	4	3
84	1900	1/23	29°15'N	179°42'W	68.0	200	20	68.0	67.0	1019.0	01	3	6	9	4
85	0000	1/24	29°09'N	179°07'W	67.5	240	15	70.1	67.2	1018.9	02	6	2	9	4
86	0600	1/24	28°46'N	178°46'W	68.0	280	16	70.0	64.5	1019.4	03	4, 6	7	9	4
87	1200	1/24	28°27'N	178°10'W	69.5	270	16	69.8	63.0	1020.9	02	X	2	9	3
88	1200	2/1	28°39'N	178°32'W	69.0	290	11	78.0	78.2	1016.4	02	8	5	9	3
89	1800	2/1	28°59'N	179°19'W	68.0	270	10	70.0	68.0	1014.7	50	X	9	0	2
90	0000	2/2	29°19'N	179°54'E	67.0	290	07	64.0	61.0	1015.4	51	0	9	7	3

Table 5.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 27, January 5 to February 21, 1955 (For coded values see H. O. Pub 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1955	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
91	0320	2/2	29°31'N	179°20'E	65.9	220	18	64.2	61.8	1013.3	61	6	8	7	3
92	0845	2/2	30°00'N	179°31'E	66.3	280	15	64.8	59.5	1014.7	21	6	8	8	3
93	1340	2/2	30°52'N	179°41'E	65.5	330	10	64.0	59.5	1014.0	01	4	3	7	3
94	1725	2/2	31°08'N	179°52'E	65.5	320	10	62.8	55.8	1014.3	02	4, 6	6	9	3
95	2115	2/2	31°33'N	179°53'E	64.6	280	10	63.0	56.5	1015.4	02	3	6	9	3
96	0044	2/3	32°01'N	179°50'E	65.0	280	10	64.0	58.5	1014.4	03	6	8	8	3
97	0350	2/3	32°34'N	179°56'W	64.8	290	19	62.0	56.0	1014.6	15	5, 6	7	9	4
98	1030	2/3	32°59'N	179°57'W	62.0	330	34	57.0	53.0	1017.4	02	6	9	8	5
99	1445	2/3	33°27'N	180°00'	62.5	330	30	55.5	50.0	1017.8	03	8	6	8	5
100	1810	2/3	33°49'N	179°56'E	62.0	330	30	54.5	50.0	1020.0	02	8	3	9	5
101	0015	2/4	34°25'N	179°52'E	62.5	000	29	54.0	47.0	1023.0	02	8	5	8	6
102	0810	2/4	35°08'N	179°51'E	56.0	030	22	54.0	46.5	1027.4	03	8	6	8	5
103	1230	2/4	35°30'N	179°44'W	60.0	030	24	53.0	45.8	1028.4	02	6	8	8	5
104	1805	2/4	36°25'N	179°25'E	57.0	030	18	55.0	47.5	1031.0	03	8	7	7	5
105	2010	2/4	36°43'N	179°28'E	58.2	060	21	49.8	44.7	1031.8	02	4	4	9	5
106	0215	2/5	36°49'N	179°43'W	60.5	050	22	51.8	47.0	1033.4	02	8	3	9	5
107	0735	2/5	36°58'N	178°47'W	57.6	090	20	51.5	45.5	1034.0	02	8	3	9	5
108	1315	2/5	37°13'N	177°40'W	58.0	050	15	53.5	47.0	1037.0	02	8	5	8	5
109	1900	2/5	37°12'N	177°07'W	57.9	060	20	51.5	46.5	1035.9	02	8	3	9	5
110	0000	2/6	37°06'N	176°11'W	57.2	100	18	52.8	46.9	1036.8	02	8	3	9	5
111	0405	2/6	37°00'N	175°32'W	58.2	120	16	51.4	46.9	1035.9	02	8, 4, 1	4	9	4
112	1100	2/6	36°56'N	174°47'W	55.7	140	10	50.5	46.2	1037.6	02	8	2	9	3
113	1500	2/6	36°52'N	174°05'W	53.5	120	10	50.0	45.5	1037.4	02	8	2	9	3
114	1915	2/6	36°49'N	173°20'W	53.0	080	20	52.9	46.9	1036.0	02	6	2	9	3
115	0000	2/7	36°21'N	173°20'W	55.0	110	22	52.1	46.7	1034.9	02	6	9	9	3
116	0330	2/7	35°48'N	173°24'W	56.0	140	20	53.0	47.1	1033.4	02	7	9	9	4
117	0630	2/7	35°20'N	173°27'W	57.1	140	19	52.8	47.2	1032.9	02	7	7	9	4
118	1200	2/7	34°52'N	173°22'W	57.5	130	23	54.8	49.4	1031.0	02	7	8	9	4
119	1540	2/7	34°27'N	173°17'W	58.0	150	24	55.0	49.0	1029.4	02	6	8	8	4
120	1715	2/7	34°09'N	173°13'W	58.0	180	19	57.0	52.0	1029.4	02	0	8	8	3

Table 5.--Summary of observations at bathythermograph lowerings, *Hugh M. Smith* cruise 27, January 5 to February 21, 1955 (For coded values see H. O. Pub 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1955	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Baro-meter, mb.	Wea-ther	Clouds		Visi-bili-ty	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
121	2220	2/7	33°42'N	173°08'W	58.0	180	17	59.0	52.5	1028.9	02	0	8	8	3
122	0130	2/8	33°20'N	173°04'W	59.0	150	22	60.5	54.5	1026.0	02	0	8	8	4
123	0820	2/8	32°30'N	173°02'W	61.1	190	16	60.8	55.4	1027.6	01	5	8	9	3
124	1245	2/8	32°00'N	173°02'W	61.1	180	17	62.0	57.0	1026.4	01	6	7	9	3
125	1640	2/8	31°33'N	173°03'W	61.0	160	13	62.0	56.5	1025.4	02	6	6	9	2
126	1950	2/8	31°00'N	172°57'W	65.0	140	1*	64.0	57.0	1027.4	02	6	8	9	2
127	2345	2/8	30°33'N	172°52'W	62.0	140	2*	64.0	57.0	1027.0	01	8	1	9	2
128	0330	2/9	30°07'N	172°47'W	62.9	130	3*	63.0	57.5	1024.7	02	8	1	9	3
129	0820	2/9	29°35'N	172°42'W	63.2	080	3*	62.8	57.1	1026.6	02	8	2	9	2
130	1310	2/9	29°04'N	172°42'W	66.0	080	3*	64.2	58.6	1026.0	03	8	6	9	3
131	1650	2/9	28°21'N	172°40'W	67.5	080	5*	64.0	57.5	1024.4	03	8	7	8	3
132	1920	2/9	28°00'N	172°37'W	68.0	080	4*	67.0	59.0	1025.9	01	6	8	9	3
133	0030	2/10	27°31'N	172°24'W	70.0	100	4*	68.0	60.0	1025.0	03	6	7	9	4
134	0420	2/10	27°02'N	172°13'W	70.2	110	5*	68.0	58.9	1024.4	02	8	6	9	4
135	0800	2/10	26°32'N	171°57'W	70.8	090	5*	68.1	61.0	1025.3	02	8	3	9	4
136	1030	2/11	26°06'N	171°21'W	69.9	050	5*	67.5	61.5	1025.4	01	8	4	9	4
137	1430	2/11	26°27'N	170°57'W	70.0	050	5*	67.0	60.5	1024.4	02	8	4	9	4
138	1810	2/11	26°47'N	170°34'W	69.0	050	5*	64.5	62.0	1025.9	03	8	6	7	4
139	2210	2/11	27°05'N	170°07'W	68.7	050	5*	69.0	61.0	1027.1	03	8	7	9	4
140	0215	2/12	27°24'N	169°40'W	68.0	040	5*	67.0	61.5	1025.9	02	7	8	8	4
141	0600	2/12	27°43'N	169°13'W	67.3	050	7*	66.2	58.9	1027.1	02	7	8	9	5
142	1000	2/12	28°00'N	168°42'W	67.0	050	5*	65.5	58.5	1029.9	01	8	3	9	4
143	1545	2/12	28°19'N	168°13'W	68.5	050	5*	64.0	57.0	1027.4	02	8	4	9	4
144	2010	2/12	28°37'N	167°47'W	68.0	050	5*	65.5	58.0	1029.8	01	8	3	9	4
145	2345	2/12	28°58'N	167°15'W	68.0	080	5*	65.8	58.0	1029.4	02	8	3	9	4
146	0250	2/13	29°14'N	166°48'W	67.0	080	5*	67.5	60.0	1029.0	02	8	3	9	4
147	0505	2/13	29°30'N	166°44'W	66.8	080	5*	64.0	58.5	1030.1	02	8	2	9	4
148	1110	2/13	30°00'N	166°42'W	66.9	040	5*	61.8	57.8	1031.0	02	8	2	9	4
149	1445	2/13	30°30'N	166°46'W	66.1	040	4*	61.5	56.5	1030.4	03	8	4	9	3
150	1830	2/13	30°57'N	166°49'W	66.0	090	3*	59.0	54.9	1031.4	02	8	4	9	3

* Anemometer failed; Beaufort force

Table 5.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 27, January 5 to February 21, 1955(For coded values see H. O. Pub 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1955	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
151	2325	2/13	31°32'N	166°46'W	62.3	090	3*	65.0	57.0	1031.0	01	8	2	9	3
152	0305	2/14	32°00'N	166°45'W	62.0	090	3*	61.0	56.0	1029.9	03	8	4	9	3
153	0710	2/14	32°27'N	166°40'W	60.0	120	3*	59.1	55.1	1032.9	02	7,8	6	9	3
154	1240	2/14	33°00'N	166°40'W	59.8	140	3*	60.2	55.5	1030.2	02	7,8	6	9	3
155	1615	2/14	33°48'N	166°39'W	58.3	120	2*	62.0	57.0	1029.1	03	7,8	8	8	2
156	1945	2/14	34°22'N	166°37'W	57.6	160	2*	60.1	56.0	1028.9	02	0	8	8	2
157	0100	2/15	34°54'N	166°38'W	56.5	140	2*	60.0	57.0	1027.4	03	0	8	9	2
158	0515	2/15	35°30'N	166°40'W	55.1	180	3*	57.5	55.3	1025.5	02	6	8	9	2
159	1050	2/15	36°01'N	166°44'W	55.1	210	4*	56.8	55.2	1021.6	02	X	8	8	3
160	1415	2/15	36°32'N	166°43'W	55.0	220	4*	56.5	55.5	1019.4	61	X	9	4	3
161	1725	2/15	37°00'N	166°43'W	54.9	220	6*	57.0	56.0	1016.4	50	0	9	7	4
162	2310	2/15	37°02'N	166°00'W	54.2	220	5*	56.0	55.0	1016.4	50	X	9	5	4
163	0320	2/16	37°05'N	165°00'W	54.0	270	4*	55.0	53.0	1016.4	45	X	9	1	4
164	0740	2/16	37°07'N	164°11'W	54.4	290	4*	53.3	50.5	1018.0	01	0	8	8	4
165	1215	2/16	37°07'N	163°36'W	53.1	300	3*	53.5	49.5	1019.1	02	0	7	9	3
166	1520	2/16	37°04'N	162°55'W	53.0	290	3*	54.0	50.5	1018.4	01	4	3	9	2
167	1820	2/16	37°00'N	162°20'W	52.1	300	5*	53.0	49.5	1018.9	02	8	3	9	3
168	2340	2/16	36°59'N	161°31'W	54.0	330	5*	50.2	46.2	1021.6	01	4,8	4	9	4
169	0330	2/17	37°00'N	160°46'W	55.0	330	5*	50.0	44.0	1023.1	02	4,8	4	9	4
170	0710	2/17	36°56'N	160°05'W	54.8	330	5*	49.4	43.5	1024.2	02	8	3	9	4
171	1155	2/17	36°30'N	160°01'W	54.8	270	3*	49.8	44.2	1024.1	02	8	3	9	4
172	1500	2/17	36°00'N	159°57'W	54.2	280	2*	51.0	45.0	1024.9	01	4	2	9	3
173	1815	2/17	35°30'N	159°53'W	55.0	040	2*	51.0	45.0	1026.9	02	1,2	2	9	3
174	2205	2/17	35°00'N	159°50'W	57.0	120	2*	54.0	47.0	1027.4	01	4	1	9	3
175	0115	2/18	34°30'N	159°47'W	57.5	120	2*	53.0	47.0	1026.0	02	4	1	9	3
176	0435	2/18	34°00'N	159°42'W	57.0	140	2*	53.1	48.5	1025.8	02	1,4	1	9	3
177	0945	2/18	33°30'N	159°39'W	60.3	120	3*	54.9	50.5	1026.4	02	4	1	9	3
178	1255	2/18	33°00'N	159°35'W	60.8	120	3*	56.0	51.5	1026.9	02	4	1	9	3
179	1615	2/18	32°27'N	159°30'W	60.0	140	2*	57.5	51.9	1026.9	02	4	1	9	3
180	2045	2/18	31°52'N	159°28'W	61.5	140	2*	61.0	55.0	1027.3	03	4,8	2	9	3

* Anemometer failed; Beaufort force

Table 5.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 27, January 5 to February 21, 1955(For coded values see H. O. Pub 606-C) (cont'd)

Ser. No.	Time, GCT	Date, 1955	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Baro-meter, mb.	Wea-ther	Clouds		Visi-bili-ty	Sea
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover		
181	2330	2/18	31°28'N	159°25'W	63.5	140	4*	61.5	55.5	1024.9	02	1,4	3	9	3
182	0215	2/19	31°00'N	159°22'W	62.9	070	2*	61.2	56.0	1025.0	02	1	4	9	2
183	0730	2/19	30°30'N	159°18'W	65.0	080	4*	63.0	57.5	1027.9	02	1	2	9	3
184	1055	2/19	30°00'N	159°15'W	66.0	090	3*	64.5	58.2	1026.7	02	1	2	8	3
185	1400	2/19	29°30'N	159°12'W	65.5	120	4*	65.0	57.0	1024.9	02	X	2	8	3
186	1830	2/19	29°00'N	159°89'W	66.5	120	3*	66.0	60.5	1025.6	03	4,8	6	8	3
187	2150	2/19	28°28'N	159°05'W	67.5	120	5*	68.5	64.0	1024.4	03	4,8	8	8	4
188	0055	2/20	28°00'N	159°03'W	69.6	080	5*	68.2	63.2	1021.9	02	8	6	8	4
189	0605	2/20	27°30'N	158°56'W	69.2	080	5*	68.0	63.0	1022.5	02	8	6	8	4
190	0945	2/20	27°00'N	158°53'W	70.0	080	5*	69.0	63.5	1021.4	01	8	4	9	4
191	1320	2/20	26°30'N	158°47'W	70.0	070	5*	69.0	63.0	1018.4	02	X	2	9	4
192	1810	2/20	26°03'N	158°45'W	70.5	070	5*	67.5	65.0	1018.0	50	8	7	8	4
193	2140	2/20	25°30'N	158°43'W	71.5	070	4*	70.5	67.5	1016.9	50	6	8	7	4
194	0100	2/21	25°00'N	158°40'W	70.0	060	5*	70.5	67.3	1012.6	15	6	6	8	5
195	0455	2/21	24°39'N	158°35'W	71.0	060	2*	70.3	68.2	1011.7	01	6	5	8	5
196	1055	2/21	24°00'N	158°28'W	72.0	090	3*	71.0	68.0	1010.9	02	6	2	9	3
197	1400	2/21	23°30'N	158°27'W	72.0	200	2*	71.0	67.0	1008.9	02	X	2	9	2
198	1850	2/21	23°00'N	158°24'W	72.0	200	2*	79.8	68.2	1000.1	16	8	4	9	3

* Anemometer failed; Beaufort force

Table 6.--Log of ship's weather observations, Hugh M. Smith cruise 27, January 5 to February 21, 1955. Results in International Ship's Weather Code, January 1955

Date, 1955	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
1/7	22.9°N	160.1°W	0000	98	00	00	03	0	1013.8	8	0.6	78.8	69.0	76.2	4	3	3	6	1	0	09	3	3
1/7	23.2°N	160.9°W	0600	97	05	19	03	2	1014.4	1	1.0	74.0	68.5	74.1	8	8	4	5	X	X	05	X	4
1/7	23.6°N	161.7°W	1200	97	09	22	02	2	1014.4	0	0.4	73.0	69.0	74.2	8	8	0	5	X	X	09	X	4
1/7	23.9°N	162.4°W	1800	99	17	15	02	1	1013.8	3	1.6	73.5	67.5	74.7	4	4	3	4	0	0	09	3	4
1/8	23.1°N	162.5°W	0000	99	17	17	01	1	1014.0	0	2.4	75.5	70.5	74.7	1	1	0	4	0	0	19	3	4
1/8	23.8°N	162.4°W	0600	98	17	15	02	1	1015.4	3	1.6	74.4	70.8	74.9	6	6	8	5	0	0	23	3	5
1/8	23.6°N	164.1°W	1200	92	19	27	50	1	1016.0	1	0.6	71.0	70.0	74.7	6	6	8	5	0	0	23	3	5
1/8	23.2°N	155.2°W	1800	98	14	15	16	2	1016.9	3	1.6	73.6	70.9	74.1	7	7	4	3	0	0	14	3	3
1/9	22.1°N	165.1°W	0000	98	18	12	01	1	1016.2	8	2.2	77.0	72.0	76.0	3	3	2	3	0	0	15	3	3
1/9	22.6°N	166.9°W	0600	99	16	09	02	0	1017.4	1	1.2	75.5	71.4	76.0	1	1	1	5	0	0	11	3	2
1/9	22.6°N	167.6°W	1200	97	12	18	64	0	1017.5	3	0.0	74.8	71.2	75.9	5	5	3	4	0	0	11	3	3
1/9	22.3°N	168.1°W	1800	99	15	10	02	0	1017.4	3	0.6	75.0	72.0	76.1	3	2	2	5	8	0	13	3	3
1/10	21.7°N	169.1°W	0000	99	19	15	02	1	1016.9	8	2.2	78.0	74.0	77.0	3	2	2	5	6	0	13	3	4
1/10	21.6°N	170.2°W	0600	99	19	07	02	0	1017.5	3	1.0	76.5	72.5	76.9	2	2	2	5	0	0	14	3	4
1/10	21.5°N	170.1°W	1200	98	21	05	01	1	1017.6	6	0.6	77.0	72.5	77.2	1	1	1	5	0	9	14	3	3
1/10	21.1°N	172.1°W	1800	98	27	10	01	5	1018.4	3	1.0	75.1	71.5	77.0	3	3	2	5	0	0	14	3	3
1/11	20.7°N	172.5°W	0000	99	02	20	62	2	1019.2	8	1.6	74.0	70.0	76.2	6	4	6	4	8	0	35	3	5
1/11	20.5°N	173.1°W	0600	97	03	27	02	2	1020.4	3	2.0	74.5	69.5	75.2	6	4	4	5	6	0	32	3	6
1/11	20.2°N	174.4°W	1200	98	05	35	03	2	1022.0	5	0.2	72.5	65.5	75.5	8	4	4	5	9	X	02	3	6
1/11	19.8°N	175.1°W	1800	97	08	32	02	2	1023.4	3	2.0	72.0	64.8	76.6	6	6	4	5	0	0	07	3	8
1/12	20.6°N	175.3°W	0000	97	08	31	01	2	1023.0	8	2.6	74.0	65.0	76.8	2	2	1	5	0	0	05	3	8
1/12	20.6°N	176.3°W	0600	97	07	27	02	2	1023.9	3	1.8	73.5	64.5	76.5	6	6	4	5	0	0	05	3	6
1/12	20.8°N	176.1°W	1200	99	08	18	02	1	1023.4	8	0.6	73.5	65.0	76.8	5	X	X	X	X	X	05	3	6
1/12	20.8°N	177.4°W	1800	99	07	22	02	X	1023.9	X	X	73.5	66.0	76.0	2	X	X	X	X	X	X	X	X
1/13	21.1°N	178.0°W	0000	99	09	22	01	1	1022.0	8	2.2	78.0	68.5	77.2	2	2	1	5	0	0	09	3	4
1/13	21.4°N	178.9°W	0600	99	09	20	02	0	1023.0	3	0.6	75.0	65.5	77.1	1	1	1	4	0	0	09	3	4
1/13	21.8°N	179.8°W	1200	99	08	18	02	0	1022.9	6	1.0	74.5	66.5	77.0	3	3	4	5	0	0	09	3	4
1/13	22.0°N	179.4°E	1800	99	09	20	02	X	1023.0	3	0.6	75.5	67.5	76.5	4	4	4	5	0	0	07	3	3
1/14	22.2°N	178.5°E	0000	99	09	16	03	1	1021.0	8	2.0	77.5	67.5	76.7	7	7	4	5	0	0	08	3	3
1/14	22.5°N	177.6°E	0600	98	09	18	02	2	1019.9	3	0.2	76.0	67.0	76.5	7	7	4	4	0	0	08	3	3

Table 6.--Log of ship's weather observations, Hugh M. Smith cruise 27, January 5 to February 21, 1955. Results in International Ship's Weather Code, January 1955 (cont'd)

Date, 1955	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
1/14	22.7°N	177.2°E	1200	98	07	08	02	2	1020.4	3	0.0	75.5	67.0	76.8	7	7	4	4	0	0	08	3	3
1/14	23.0°N	175.8°E	1800	98	01	10	02	2	1019.9	3	0.6	75.1	67.0	76.0	7	7	4	4	0	0	01	3	3
1/15	23.3°N	174.8°E	0000	99	08	13	01	1	1018.0	8	3.2	75.0	66.5	75.0	1	1	4	5	0	0	11	3	2
1/15	23.6°N	174.0°E	0600	99	02	09	02	0	1017.9	3	1.0	76.5	67.0	76.0	1	1	4	5	0	0	34	3	6
1/15	23.9°N	173.3°E	1200	99	02	19	02	0	1019.9	3	0.6	71.5	67.2	75.0	1	1	4	5	0	0	34	3	6
1/15	24.0°N	172.6°E	1800	94	10	35	50	2	1020.7	5	1.6	70.0	65.8	76.2	8	8	8	5	X	X	10	3	6
1/16	24.2°N	171.9°E	0000	99	03	33	03	6	1023.0	0	0.2	74.0	66.5	76.2	6	6	4	5	6	0	08	3	7
1/16	24.6°N	171.1°E	0600	99	08	31	01	2	1022.5	3	1.0	71.5	63.0	76.3	3	3	4	5	0	0	08	3	7
1/16	24.9°N	170.4°E	1200	99	07	19	02	0	1024.4	0	0.4	71.5	63.0	73.0	3	3	4	5	0	0	08	3	5
1/16	25.2°N	169.5°E	1800	98	09	30	03	1	1023.0	3	0.6	71.5	65.5	72.5	7	7	4	5	0	0	08	3	5
1/17	26.0°N	169.5°E	0000	99	10	18	02	1	1024.9	0	0.0	73.0	63.5	71.8	3	3	4	5	0	0	08	3	5
1/17	26.7°N	169.6°E	0600	99	10	16	02	0	1024.8	3	0.8	69.9	62.5	70.4	0	0	0	X	0	0	08	3	4
1/17	27.5°N	169.8°E	1200	99	12	07	02	0	1025.4	3	0.2	70.0	62.2	70.0	0	0	0	X	0	0	08	3	4
1/17	28.1°N	169.8°E	1800	99	12	05	02	0	1024.0	3	0.6	68.5	61.0	70.5	0	0	0	X	0	0	08	3	2
1/18	28.8°N	169.9°E	0000	99	20	10	02	0	1023.4	6	1.0	72.0	65.1	71.4	1	1	4	5	0	0	08	3	4
1/18	29.5°N	169.6°E	0600	99	25	16	02	1	1021.8	6	0.2	70.0	65.1	70.9	4	1	1	4	3	0	25	3	3
1/18	30.2°N	170.0°E	1200	99	23	16	03	0	1021.4	8	0.6	68.5	66.0	69.5	6	0	0	9	1	0	25	3	4
1/18	31.1°N	170.6°E	1800	99	27	20	02	1	1018.0	6	0.6	66.4	64.9	67.4	4	4	1	X	1	0	25	3	4
1/19	31.8°N	170.7°E	0000	99	28	25	03	0	1017.9	8	1.6	65.1	62.5	64.8	1	1	8	4	0	0	29	3	4
1/19	32.5°N	170.9°E	0600	97	29	20	50	1	1015.0	8	1.0	62.5	62.5	62.5	8	0	0	9	2	0	29	3	4
1/19	32.5°N	171.7°E	1200	99	34	20	01	2	1018.8	3	2.0	60.0	54.9	61.5	2	X	X	X	X	X	29	3	4
1/20	32.6°N	171.4°E	0000	99	34	18	01	1	1024.0	1	1.0	56.5	51.5	61.9	3	3	2	4	0	0	33	3	7
1/20	32.4°N	173.2°E	0600	99	00	11	03	1	1024.7	5	1.0	58.0	53.0	64.0	5	5	8	4	0	0	33	3	5
1/20	32.0°N	172.9°E	1200	99	09	05	02	0	1026.4	3	0.6	58.0	50.0	63.9	2	X	X	X	X	X	30	3	5
1/20	31.9°N	173.5°E	1800	99	19	12	01	1	1025.0	3	1.0	59.0	49.5	63.5	3	1	8	X	6	0	31	3	2
1/21	31.8°N	174.0°E	0000	99	14	15	02	1	1024.9	9	1.0	61.0	53.0	65.8	3	3	4	5	0	0	33	3	4
1/21	31.5°N	174.6°E	0600	99	16	25	02	1	1021.5	8	0.6	62.9	55.6	64.5	7	7	4	5	0	0	17	2	4
1/21	31.6°N	175.2°E	1200	99	19	30	02	1	1020.4	8	1.6	63.5	56.0	63.5	3	X	X	X	X	X	17	2	4
1/21	31.4°N	175.8°E	1800	99	19	33	01	1	1016.6	8	1.6	66.0	61.5	65.5	2	X	X	X	X	X	17	3	4
1/22	31.3°N	176.3°E	0000	97	21	32	02	1	1014.9	8	1.6	68.0	64.0	65.0	6	6	4	4	0	0	18	3	6

Table 6.--Log of ship's weather observations, Hugh M. Smith cruise 27, January 5 to February 21, 1955. Results in International Ship's Weather Code, January 1955 (cont'd)

Date, 1955	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
1/22	31.0°N	176.9°E	0600	96	24	23	63	2	1015.5	3	1.6	66.8	65.1	66.5	8	8	5	3	X	X	19	3	5
1/22	30.8°N	177.4°E	1200	96	25	04	51	2	1018.4	3	1.2	65.0	63.5	66.0	9	9	X	0	X	X	18	3	3
1/22	30.4°N	177.9°E	1800	96	19	20	02	2	1018.4	3	0.2	67.0	65.0	66.0	9	9	X	0	X	X	19	3	3
1/23	30.2°N	178.4°E	0000	99	20	15	01	1	1018.8	0	1.0	68.0	65.1	65.5	6	6	6	4	0	0	24	3	3
1/23	29.9°N	178.9°E	0600	93	21	20	46	1	1017.5	3	0.6	66.0	65.8	66.2	2	2	1	4	0	0	24	3	3
1/23	29.7°N	179.5°E	1200	95	24	23	46	1	1018.9	3	0.0	67.0	66.1	66.0	9	9	X	0	X	X	24	3	3
1/23	29.2°N	179.7°W	1800	99	20	20	01	2	1019.0	5	0.0	68.0	67.0	68.0	7	3	4	4	0	9	24	3	4
1/24	29.1°N	179.1°W	0000	99	24	15	02	0	1018.9	8	0.8	70.1	67.2	67.5	1	1	4	4	0	0	24	3	4
1/24	28.8°N	178.3°W	0600	99	28	16	03	1	1019.4	3	1.0	70.0	64.5	68.0	7	7	4	4	0	0	27	3	4
1/24	28.1°N	178.1°W	1200	99	27	16	02	0	1020.9	9	0.6	69.8	63.0	69.5	1	X	X	X	X	X	27	3	2
1/24	28.2°N	177.6°W	1800	98	33	13	01	-	1020.6	3	0.6	67.5	62.5	67.5	1	1	2	4	0	0	27	3	2
2/1	29.1°N	179.3°W	1800	91	30	10	60	1	1014.7	5	0.6	70.0	67.0	68.0	9	9	X	0	X	X	27	3	1
2/2	29.3°N	179.9°E	0000	98	29	07	51	5	1015.4	8	1.2	64.0	61.0	67.0	9	0	0	9	2	0	36	3	3
2/2	29.7°N	179.4°E	0600	96	22	18	61	6	1013.1	3	0.2	63.5	62.0	65.9	8	8	6	3	X	X	14	3	3
2/2	30.3°N	179.7°E	1200	99	33	11	02	0	1014.9	3	0.0	65.5	60.0	66.1	4	4	4	4	0	0	27	3	4
2/2	31.0°N	180.0°	1800	99	32	10	02	2	1014.3	3	0.0	62.8	55.8	65.5	0	0	0	9	0	0	27	3	4
2/3	32.0°N	179.8°W	0000	99	28	10	03	1	1015.4	9	0.0	65.0	58.1	65.0	5	5	4	4	0	0	30	3	4
2/3	32.6°N	180.0°	0600	98	29	19	03	1	1015.0	3	2.6	61.0	55.5	64.5	7	7	4	4	0	0	29	3	4
2/3	33.0°N	179.9°E	1200	98	33	35	01	2	1015.0	3	0.6	57.8	51.0	63.0	4	4	4	4	0	0	30	3	6
2/3	33.8°N	179.9°E	1800	99	33	30	02	1	1020.0	3	2.0	54.5	50.0	62.0	3	2	1	4	0	1	33	3	6
2/4	34.4°N	179.9°E	0000	98	36	29	02	1	1023.0	3	0.0	54.0	47.0	62.5	5	5	1	3	0	0	34	3	8
2/4	35.0°N	179.8°E	0600	97	03	22	03	1	1027.4	3	2.6	54.0	46.5	56.0	6	6	1	3	0	0	32	3	6
2/4	35.5°N	179.7°E	1200	99	03	24	02	1	1028.4	3	0.8	53.0	45.8	60.0	7	7	4	4	0	0	33	3	6
2/4	36.4°N	179.4°E	1800	97	03	18	03	1	1031.0	3	2.0	55.0	47.5	57.0	7	7	7	4	0	0	33	3	6
2/5	36.8°N	180.0°	0000	99	07	20	02	0	1032.1	0	0.0	51.0	46.0	58.5	3	3	1	5	0	0	36	3	5
2/5	37.0°N	179.0°W	0600	99	07	16	02	0	1032.9	3	1.2	52.1	46.7	58.7	3	3	1	5	0	0	36	3	5
2/5	36.9°N	178.1°W	1200	99	10	14	02	0	1035.7	3	0.7	52.1	46.9	59.0	3	3	1	5	0	0	36	3	5
2/5	37.2°N	177.3°W	1800	99	06	24	02	0	1035.4	1	0.8	51.5	45.8	58.0	2	2	4	4	0	0	05	3	5
2/6	37.1°N	176.2°W	0000	99	10	18	02	0	1036.8	0	0.0	52.8	46.9	57.2	3	3	4	5	0	0	05	3	5
2/6	37.0°N	175.5°W	0600	99	11	16	02	0	1036.5	5	0.0	51.0	46.0	58.2	3	3	1	5	0	8	05	3	2

Table 6.--Log of ship's weather observations, Hugh M. Smith cruise 27, January 5 to February 21, 1955. Results in International Ship's Weather Code, January 1955 (cont'd)

Date, 1955	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
2/6	37.0°N	174.8°W	1200	99	14	10	02	0	1037.6	1	0.6	50.5	46.2	55.7	4	2	1	5	0	8	05	3	2
2/6	36.8°N	173.6°W	1800	99	10	21	02	0	1035.8	8	1.3	50.9	45.8	53.5	3	2	1	5	0	8	03	3	2
2/7	36.4°N	173.3°W	0000	99	11	22	02	1	1034.9	8	1.0	52.1	46.7	55.0	7	7	4	4	0	0	09	3	3
2/7	35.4°N	173.5°W	0600	99	11	22	02	1	1033.4	6	0.6	52.0	48.0	56.0	7	0	0	9	2	0	09	3	5
2/7	34.8°N	173.5°W	1200	99	13	23	02	1	1031.0	6	0.6	54.8	49.4	57.3	8	0	0	9	2	X	07	3	5
2/7	34.1°N	173.2°W	1800	98	18	19	02	2	1029.4	2	0.0	57.0	52.0	58.0	8	0	0	9	2	X	11	3	3
2/8	33.5°N	173.1°W	0000	98	15	22	03	2	1027.4	8	2.6	60.0	53.5	59.0	8	0	0	9	2	X	13	3	4
2/8	32.6°N	173.1°W	0600	97	18	16	02	2	1027.4	3	2.2	62.0	54.5	61.0	7	X	X	X	X	X	13	3	3
2/8	32.1°N	173.1°W	1200	99	17	17	01	2	1026.1	6	1.3	62.0	57.0	60.9	7	7	8	5	0	0	16	3	3
2/9	30.5°N	172.9°W	0000	99	14	04	01	1	1027.0	9	2.0	64.0	57.0	62.0	1	1	1	4	0	0	12	3	2
2/9	29.7°N	173.0°W	0600	99	14	10	02	0	1025.4	3	0.6	62.5	57.5	62.9	1	1	1	4	0	0	11	3	3
2/9	29.2°N	172.7°W	1200	99	08	10	03	0	1026.3	0	0.6	63.9	57.5	67.8	6	6	1	4	0	0	11	3	3
2/9	28.3°N	172.7°W	1700	99	08	16	02	1	1026.0	6	1.3	64.0	57.5	67.5	7	7	8	4	0	0	07	3	4
2/10	27.6°N	172.4°W	0000	99	08	16	01	2	1025.4	8	1.0	68.0	59.0	70.0	5	5	4	4	0	0	09	3	4
2/10	26.7°N	172.0°W	0600	98	08	21	03	2	1024.9	3	0.6	62.9	60.9	70.5	6	X	X	X	X	X	11	3	4
2/11	26.2°N	171.0°W	1200	99	04	17	01	1	1024.9	3	0.0	67.5	60.4	69.0	2	2	2	5	0	0	07	3	4
2/11	26.8°N	170.6°W	1800	99	05	20	03	1	1025.9	3	1.0	64.5	62.0	69.0	6	6	2	5	0	0	07	3	4
2/12	27.3°N	169.9°W	0000	98	06	21	02	2	1025.9	6	1.0	67.2	60.0	67.7	7	7	8	5	0	0	05	3	4
2/12	27.8°N	169.2°W	0600	99	05	28	02	2	1027.1	3	1.4	66.2	58.9	67.3	7	7	8	5	0	0	05	3	5
2/12	28.0°N	168.7°W	1200	99	05	20	01	1	1028.4	8	0.8	65.0	57.5	67.0	4	4	1	4	0	0	05	3	5
2/13	29.0°N	167.2°W	0000	99	08	20	02	0	1029.4	8	1.2	65.8	58.0	68.0	2	2	1	4	0	0	08	3	5
2/13	29.5°N	166.7°W	0600	99	08	20	02	0	1030.5	3	2.0	64.0	58.5	66.8	2	2	1	4	0	0	08	3	4
2/13	30.0°N	166.7°W	1200	99	04	18	02	0	1031.0	3	0.6	61.8	57.8	66.9	2	2	1	4	0	0	05	3	4
2/13	30.9°N	166.8°W	1800	99	09	08	02	0	1031.4	3	1.2	59.0	54.9	66.0	3	3	1	4	0	0	07	3	3
2/14	31.6°N	166.8°W	0000	99	09	08	01	1	1030.7	9	2.0	63.0	57.0	62.3	2	2	1	4	0	0	09	3	3
2/14	32.0°N	166.7°W	0600	99	09	08	03	0	1030.7	3	1.2	58.8	54.6	60.2	6	3	1	4	6	0	09	3	3
2/14	32.7°N	166.7°W	1200	99	14	08	02	1	1030.6	8	0.8	60.6	55.5	60.0	6	3	1	4	6	0	16	3	3
2/14	34.1°N	166.6°W	1800	99	12	05	02	1	1029.1	6	0.6	62.0	57.0	58.2	8	0	0	9	6	X	16	3	3
2/15	34.8°N	166.6°W	0000	99	14	02	03	2	1027.1	8	2.0	59.0	57.0	56.5	7	7	4	4	0	0	16	3	2
2/15	35.5°N	166.7°W	0600	99	18	10	02	2	1025.5	3	0.0	57.5	55.3	55.1	7	0	0	9	6	0	16	3	2

Table 6.--Log of ship's weather observations, *Hugh M. Smith* cruise 27, January 5 to February 21, 1955. Results in International Ship's Weather Code, January 1955 (cont'd)

Date, 1955	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
2/15	36.1°N	166.7°W	1200	98	21	15	02	2	1021.6	8	2.0	56.8	55.2	55.1	8	X	X	X	X	X	18	3	3
2/15	37.0°N	166.7°W	1800	97	21	30	62	2	1017.0	8	2.0	57.0	56.0	54.9	8	0	0	9	2	X	21	3	4
2/16	37.0°N	166.0°W	0000	95	27	15	50	5	1016.4	6	0.6	56.0	55.0	54.2	9	9	X	0	X	X	23	3	5
2/16	37.0°N	164.2°W	0600	99	30	15	01	5	1017.3	3	1.3	53.8	51.4	54.0	7	7	5	3	0	0	27	3	4
2/16	37.2°N	163.7°W	1200	99	30	10	02	1	1019.1	1	0.6	53.5	49.5	53.1	6	6	5	3	0	0	27	3	3
2/16	37.0°N	162.4°W	1800	99	30	17	02	0	1018.9	3	2.0	53.0	49.5	52.1	4	4	8	4	0	0	29	3	4
2/17	37.0°N	161.4°W	0000	99	33	17	01	2	1021.6	0	1.2	50.2	46.2	54.0	3	3	2	4	2	0	30	3	4
2/17	37.0°N	160.2°W	0600	99	32	20	02	1	1023.5	5	1.0	49.4	43.5	55.0	3	3	2	4	2	0	30	3	4
2/17	36.5°N	160.0°W	1200	99	27	10	02	1	1024.1	2	0.0	49.8	44.2	54.8	2	2	2	4	0	0	32	3	4
2/17	35.6°N	159.9°W	1800	99	04	06	02	0	1026.9	3	1.8	51.0	45.0	55.0	3	0	0	9	0	6	04	3	3
2/18	34.7°N	159.8°W	0000	99	12	06	01	0	1026.4	9	1.2	53.0	46.5	57.0	1	1	0	3	1	0	30	3	4
2/18	34.0°N	159.7°W	0600	99	14	08	02	0	1026.5	3	1.0	53.8	49.0	57.0	1	0	0	9	8	5	30	3	5
2/18	33.1°N	159.7°W	1200	99	13	15	02	0	1026.7	3	0.6	55.4	51.0	60.0	0	0	0	9	0	0	30	3	3
2/18	32.4°N	159.5°W	1800	99	12	06	03	0	1027.4	3	0.0	58.8	53.0	60.0	2	0	0	9	9	2	30	3	3
2/19	31.4°N	159.4°W	0000	99	14	15	02	0	1024.9	8	2.0	61.5	55.5	63.5	2	0	0	9	9	1	13	3	3
2/19	31.0°N	159.3°W	0600	99	07	10	02	0	1027.0	3	2.0	62.2	58.8	63.9	3	0	0	9	1	1	14	3	2
2/19	29.9°N	159.3°W	1100	99	09	10	02	0	1026.5	8	1.0	64.5	58.2	66.0	2	0	0	9	0	1	11	3	2
2/19	29.1°N	159.2°W	1800	99	12	10	03	2	1025.6	3	0.6	66.0	60.5	66.5	6	2	1	4	2	0	12	3	2
2/20	28.2°N	159.1°W	0000	99	12	20	01	1	1022.4	8	2.4	69.0	64.0	70.0	4	4	2	5	0	0	12	3	4
2/20	27.5°N	158.9°W	0600	99	08	20	03	1	1022.5	3	0.7	68.0	63.0	69.2	6	6	2	5	0	0	08	3	4
2/20	26.6°N	158.8°W	1300	99	07	20	02	1	1018.4	6	1.0	69.0	63.0	70.0	X	X	X	X	X	X	08	3	4
2/20	26.1°N	158.8°W	1800	98	07	20	50	2	1028.0	3	1.0	67.5	65.0	70.5	7	7	2	4	0	0	08	3	4
2/21	25.1°N	158.7°W	0000	92	07	20	63	2	1014.4	8	1.6	69.5	67.5	71.5	9	9	X	0	X	X	08	3	5
2/21	24.5°N	158.5°W	0700	98	06	05	01	1	1012.2	3	0.7	70.5	67.8	71.0	6	6	8	4	0	0	06	3	5
2/21	23.9°N	158.5°W	1100	99	09	10	02	1	1010.9	8	0.4	71.0	68.0	72.0	2	2	8	4	0	0	06	3	3
2/21	23.1°N	158.4°W	1800	99	20	05	16	1	1010.0	1	1.0	69.0	68.0	72.0	4	4	8	4	6	0	08	3	3

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A NEW METHOD OF HANDLING LONG-LINE GEAR USING A ROTATING TUB

By Herbert J. Mann*

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ABSTRACT

A considerable savings in manpower may be effected by operating tuna long-line gear from a rotating tub rather than by handling it in the conventional manner. Instead of using individual baskets of line which must be separated and joined together for each day's fishing, a continuous mainline is set from, and hauled into a wooden storage drum. Conventional gear requires but few changes to fit it for the new method of operation.

INTRODUCTION

This is the third report on the construction and operation of the long-line gear used by the Pacific Oceanic Fishery Investigations (POFI), U. S. Fish and Wildlife Service, in a program of exploratory tuna fishing in central Pacific waters. It describes a new technique for handling long-line gear called the "tub" method, which saves manpower as compared with conventional long-line fishing methods. Earlier descriptions of the design and operation of long line, as developed at POFI, were given by Niska (1953) and Mann (1955).

In this report, "long-lining" refers to the set-line method of fishing used in the Japanese and Hawaiian high-seas fisheries for tunas and spearfishes. The gear is constructed so that a series of baited hook droppers is suspended from a long mainline, usually several miles in length; the mainline is buoyed up at regular intervals by buoys and floatlines. Unanchored, the gear drifts with wind and current with the hooks fishing at 100 to 500 feet below the surface.

The Japanese have found long-lining to be an effective way of harvesting tuna, and a large part of the Japanese commercial tuna catch is taken by this means. The long line, however, is not utilized to any great extent by United States fishermen. Two major drawbacks to this method of fishing, as now practiced, have prevented its general acceptance by the American industry. First, the method is nonselective, as far as catch is concerned, so that fish of various species and sizes are taken on the gear. This presents no hindrance in a fresh-fish economy such as Japan possesses, in which there is a steady market demand for fresh fish of all types, but it does present some problems to the United States canning industry accustomed to dealing with fish of uniform size and species. Secondly, a comparatively large number of men are required for long-lining. The relatively low concentration of tuna in most regions of the open sea makes it necessary to set a large amount of gear over a wide area in order to insure a commercial return. Japanese vessels, fishing from 1,200 to 1,500 hooks a day, require more than 20 men for assembling, baiting, setting, hauling, and restowing the gear. An American purse seiner or live-bait vessel of comparable tonnage usually has a crew of about 12 men.

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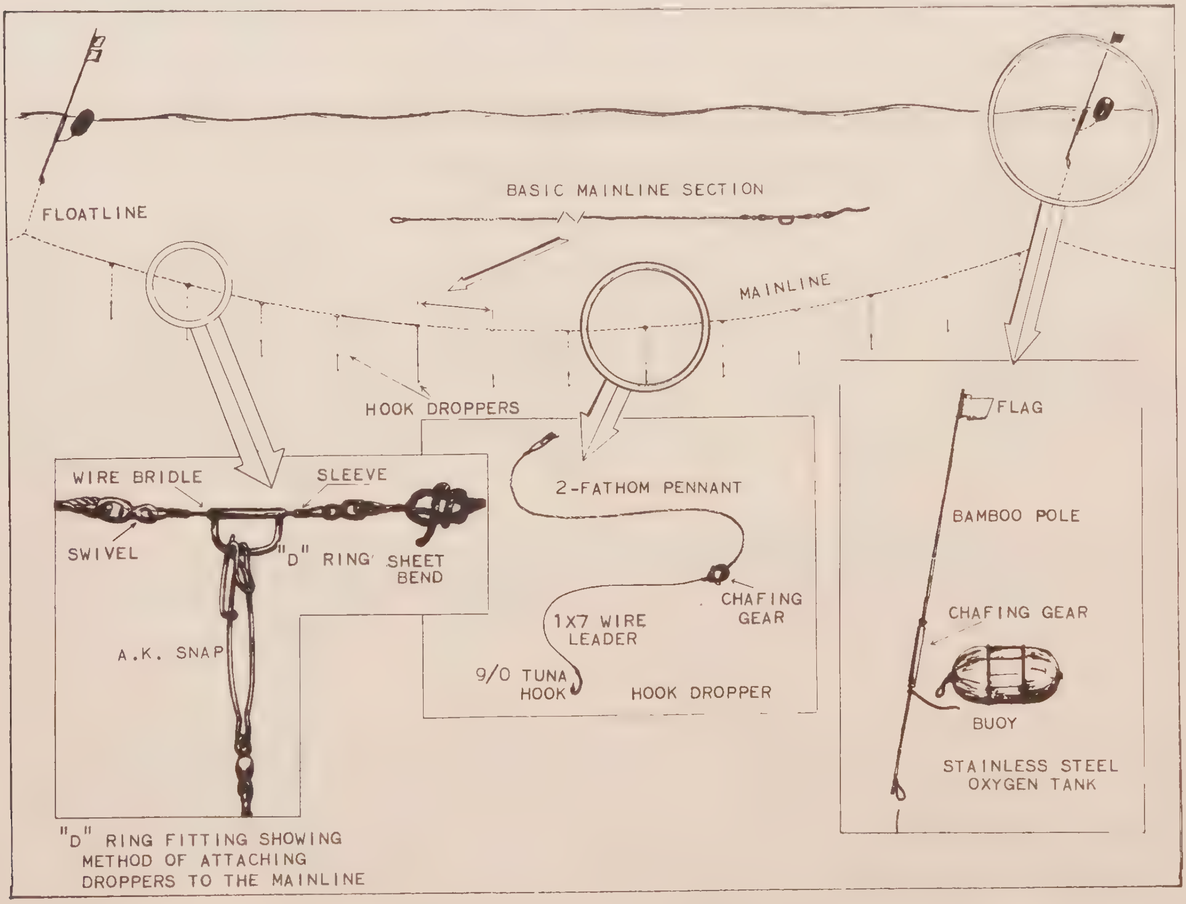
FLOATLINE
BASIC MAINLINE SECTION
MAINLINE
HOOK DROPPERS
WIRE BRIDLE
SLEEVE
SWIVEL
"D" RING
SHEET BEND
A.K. SNAP
"D" RING FITTING SHOWING METHOD OF ATTACHING DROPPERS TO THE MAINLINE
2-FATHOM PENNANT
CHAFING GEAR
1X7 WIRE LEADER
9/0 TUNA HOOK
HOOK DROPPER
FLAG
BAMBOO POLE
CHAFING GEAR
BUOY
STAINLESS STEEL OXYGEN TANK

Fig. 1 - Schematic diagram of one basket of tub gear.

POFI has made several attempts to modify the long line so as to reduce the number of men necessary to operate the gear. For example, a "drum line," which consisted of a mainline in one continuous length reeled on a wooden drum instead of being broken down into separate units was tried experimentally. In another scheme, wire rope was substituted for cotton twine for the mainline, and high-speed multiple-drum winches were used to set and retrieve the gear. In both of these methods difficulty was experienced with winch inertia problems and with the devices for attaching droppers to the mainline in the setting operation. Neither scheme offered enough promise to justify the continuation of its development.

RECENT INNOVATIONS

The latest modification of tuna long-lining, the tub method described here, has proven successful in experimental fishing. With this method, the mainline, in one continuous length, is set from, and hauled into the wooden storage tub that gives this method its name. The droppers and floatlines are detachable and are removed from the mainline during hauling operations and reattached during the setting process.

By eliminating the handling of the mainline, a considerable saving in labor is effected. Fishing cruises aboard the Bureau's research vessels *John R. Manning* and *Commonwealth*, during which the new method and the conventional method of handling gear were compared, showed that the usual POFI set of from 60 to 100 baskets of gear could be made by 5 men, or less, using the tub method, whereas, the full crew of 11 men was necessary to operate conventional gear.

Shown in figure 1 is a schematic representation of one basket of POFI experimental long line. Except for the "D" ring (shown in the insert, lower left), the gear is of the standard POFI design described in detail in a previous report (Mann 1955). The "D" ring, a nonstandard fitting designed by POFI, is also a new development. Its function is to provide free-swivelling action between dropper and mainline at any angle of pull. Formerly the AK snaps were clipped directly to the wire bridle. This means of attachment ordinarily permitted the dropper to swivel around the mainline and thus prevented tangles of dropper and mainline, when the gear was being hauled

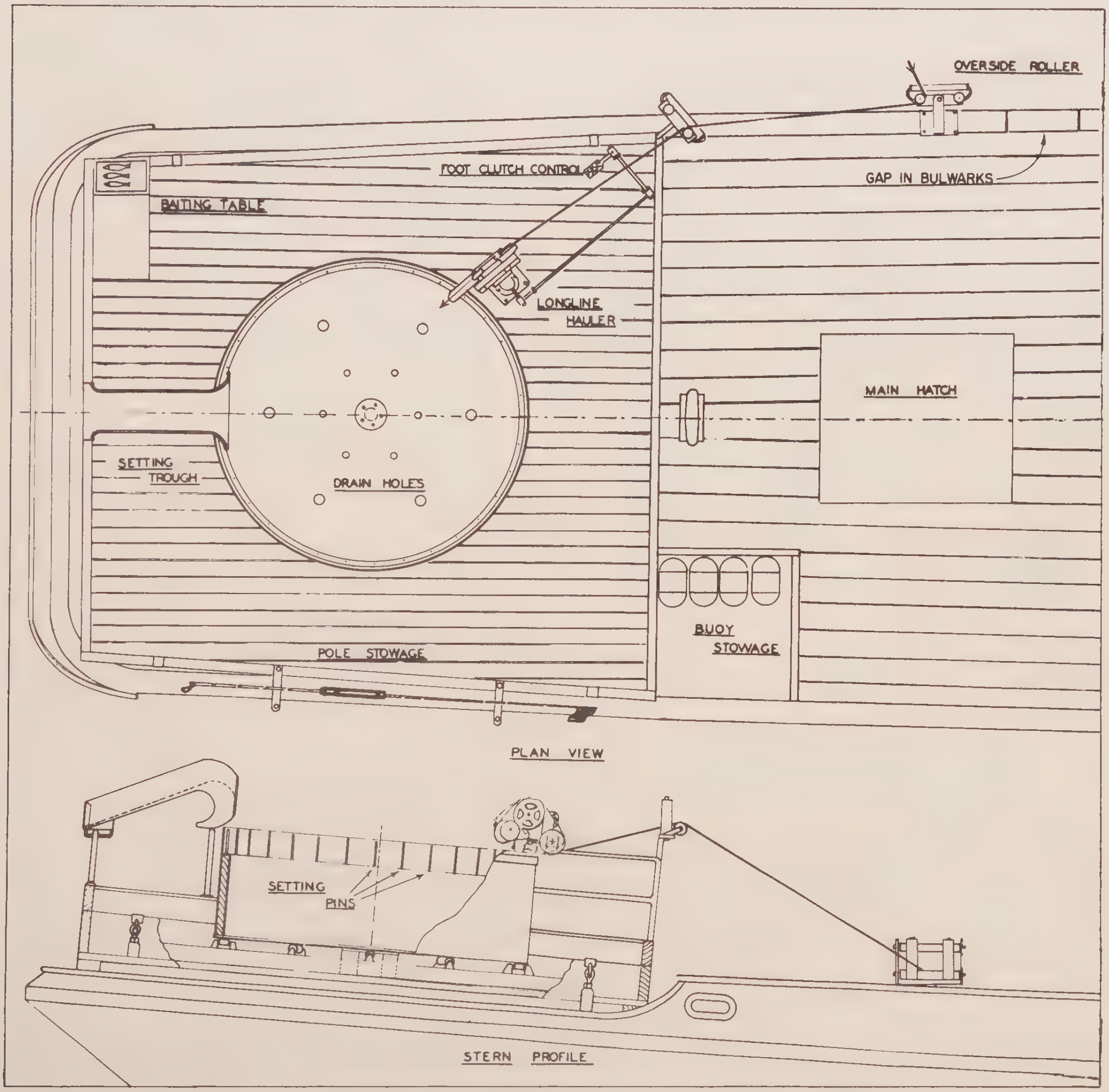
OVERSIDE ROLLER
FOOT CLUTCH CONTROL
GAP IN BULWARKS
BAITING TABLE
LONGLINE HAULER
MAIN HATCH
SETTING TROUGH
DRAIN HOLES
BUOY STOWAGE
POLE STOWAGE
PLAN VIEW
SETTING PINS
STERN PROFILE

Fig. 2 - Installation of the line-stowage tub on the *John R. Manning*.

aboard the vessel, but it frequently failed to function properly when large fish pulled the dropper parallel to the mainline. At acute angles under strong tension, the snap ceased to have any swivelling action and sometimes was pulled out of shape or broken.

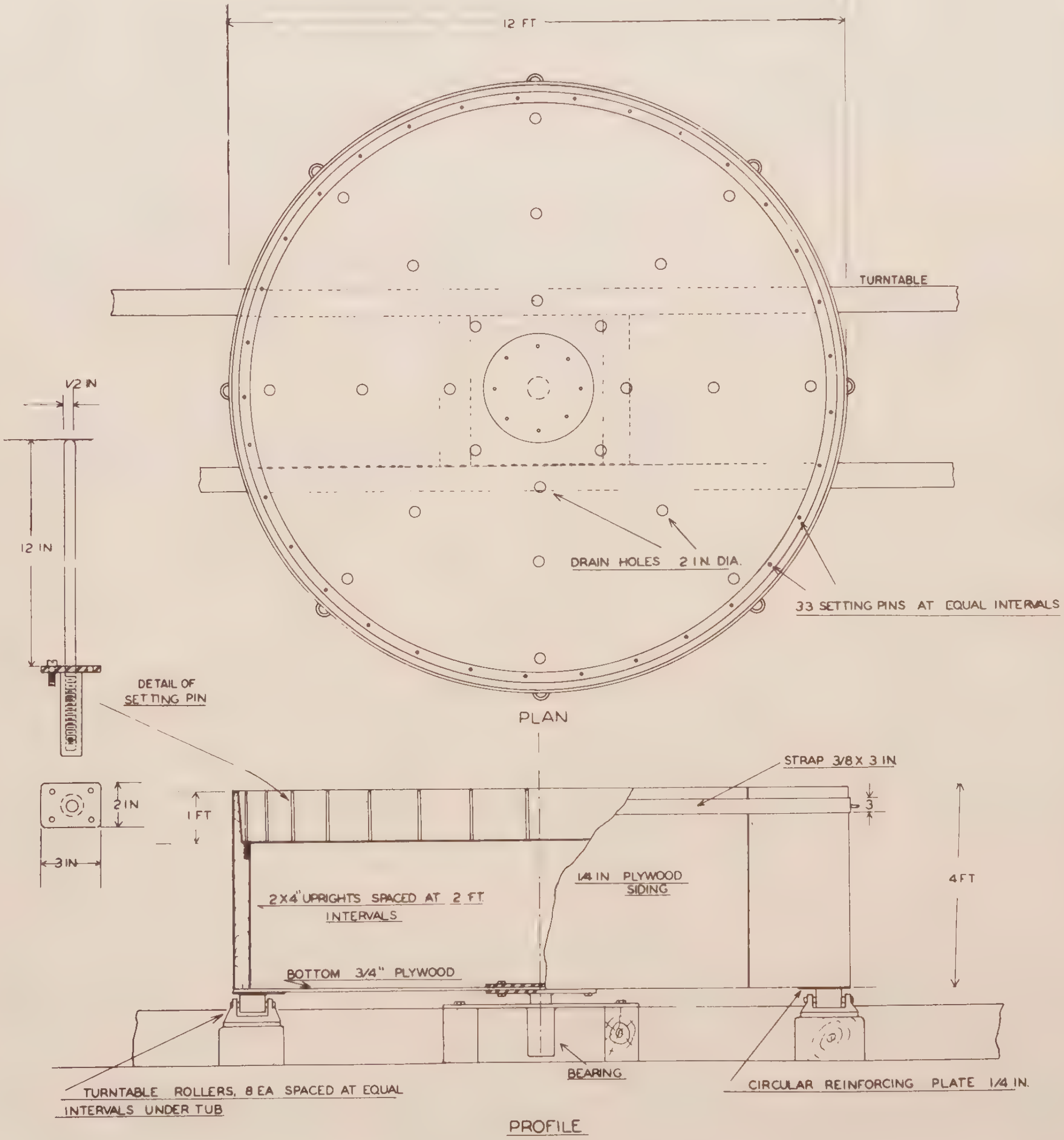
12 FT
TURNTABLE
1/2 IN
12 IN
DRAIN HOLES 2 IN. DIA.
33 SETTING PINS AT EQUAL INTERVALS
DETAIL OF SETTING PIN
PLAN
STRAP 3/8 X 3 IN
3
2 IN
3 IN
1 FT
4 FT
1/4 IN PLYWOOD SIDING
2X4" UPRIGHTS SPACED AT 2 FT INTERVALS
BOTTOM 3/4" PLYWOOD
TURNTABLE ROLLERS, 8 EA SPACED AT EQUAL INTERVALS UNDER TUB
BEARING
CIRCULAR REINFORCING PLATE 1/4 IN.
PROFILE

Fig. 3 - Construction details of line storage tub.

The new "D" ring maintains proper swivelling action with the dropper leading in any direction. The rings are fabricated from a section of stainless steel tubing $\frac{5}{16}$-inch outside diameter and $\frac{3}{32}$-inch inside diameter. The lower section of $\frac{3}{16}$-inch diameter stock is formed in a U-shape and welded to the tube section. The rings are threaded on a wire bridle made up of a 6-inch length of $\frac{3}{32}$-inch diameter 7 x 7 stainless steel wire rope. Wire loops holding brass swivels at each end of the bridle are made by pressing Nicopress fittings on the wire with a hand tool. Swivels are used to relieve torque which develops while the long line is being brought in by the hauler.

CONSTRUCTION OF THE TUB

Figure 2 is a schematic representation of the experimental long-line tub installed on the M/V John R. Manning. The tub is mounted on the stern turntable in the space normally occupied by the purse seine on this type of vessel. Ample work space is left on all sides between the tub and the railing. A heavy combination thrust and side bearing, bolted to the main deck, permits the tub to rotate in either direction. The bottom rim of the tub, reinforced with a circular steel plate, runs on a set of 8 cast-iron rollers formerly used to support the purse-seine turntable. The deck gratings and railing on top of the turntable provide a safe working space above the wash of the seas and make the tub easily accessible during fishing operations.

Figure 3 shows construction details of the tub. Inner and outer shells of the tub consist of panels of $\frac{1}{4}$-inch marine plywood with the grain running vertically. The two shells are separated by 2 x 4-inch uprights. The bottom is constructed of two panels of $\frac{3}{4}$-inch plywood. Two-inch drain holes are spaced at intervals around the bottom. The tub is strengthened by circular steel bands of $\frac{3}{8}$- x 3-inch strap welded to form rings around the outside walls.

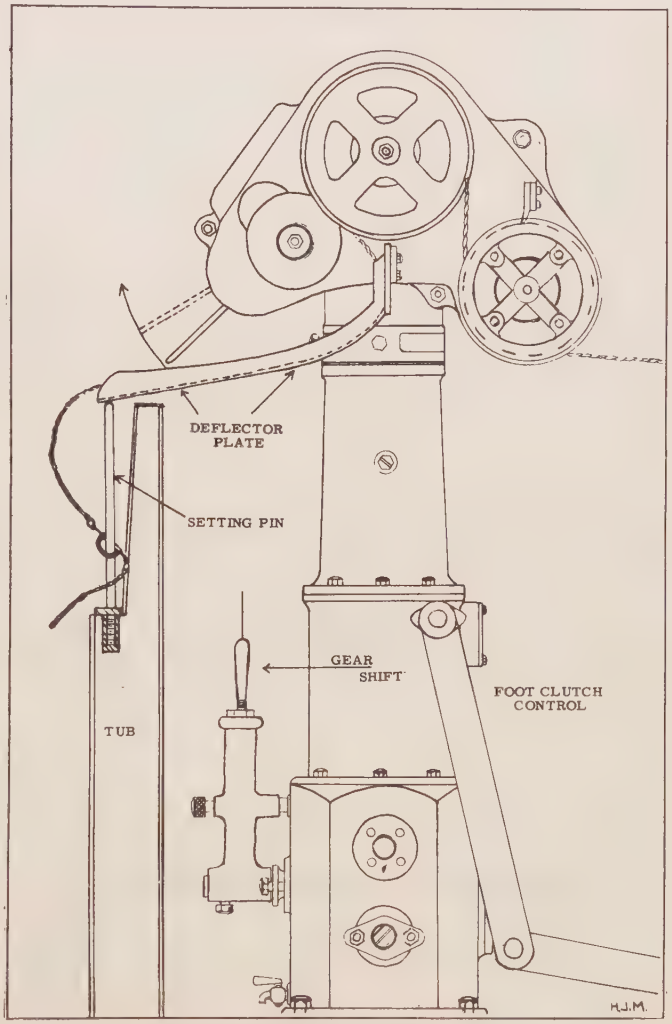

Fig. 4 - Arrangement of the tub and long-line hauler.

Setting pins, of $\frac{1}{2}$-inch diameter x 12-inch length, made from stainless steel rod, are spaced at equal intervals around the rim inside the tub. The pins are threaded into stainless steel bases firmly mounted on the step. These pins are securely mounted because severe strains are exerted on them during hauling operations when the mainline is packed down into the tub by trampling upon it.

The tub on the John R. Manning is $11\frac{1}{2}$ feet inside diameter and 4 feet in height. This size allows for storage of 100 baskets of POFI mainline gear. The tub, as presently designed, is rotated by hand. If large amounts of long-line gear are to be fished commercially, some system of turning the tub by power is desirable.

THE SETTING TROUGH

The setting trough (fig. 2) is a demountable sheet metal form used to confine and guide the outgoing mainline during the setting process. In general appearance it is similar to the type used in the halibut fishery of the eastern North Pacific. The inboard lip of the trough is mounted above the tub edge and slightly inboard of the setting pins. In the original installation, some difficulty was experienced in getting the "D" rings to lift smoothly from their setting pins. It was necessary, therefore, to make the trough easily adjustable in height and distance in respect to the tub edge so that the proper relation between pin and trough could be established.

THE LONG-LINE HAULER

The gear is hauled by a conventional Japanese long-line hauler. This type of winch, turning at high speed with low inertia, is especially adapted to the long-line operation in which the mainline must be stopped frequently so that droppers can be removed.

The hauler is mounted on the turntable as close as possible to the edge of the tub. Because of the projecting gear shift lever of the winch, the hauler cannot be mounted with its inboard sheave over the tub and a deflector plate is used to bridge the gap between hauler and tub (see fig. 4). This plate is adjustable so that the incoming line can be thrown at various angles by changing the height of the inboard end of the plate.

The hauler is controlled by a foot clutch mounted at the rail, so that the winch operator has a clear view of the line coming aboard. To aid in landing fish, the line is led through overside rollers mounted on the starboard side of the main deck. The droppers and floatlines are detached at this lower level.

On POFI vessels the long-line hauler is driven by a 3 hp. electric motor through a 5:1 gear reduction, or by a 14 hp. hydraulic drive. An input speed of 300 revolutions per minute yields a line speed of about 1,000 feet per minute in high gear and 500 feet per minute in low gear.

OPERATION OF THE GEAR

Before leaving on a fishing cruise, baskets of mainline are knotted together and fed through the line hauler and stowed in the storage tub. No attempt is made to coil the line down uniformly but it is distributed on the bottom of the tub by changing the angle of the deflector plate from time to time so that line is thrown from one side of the tub to the other.

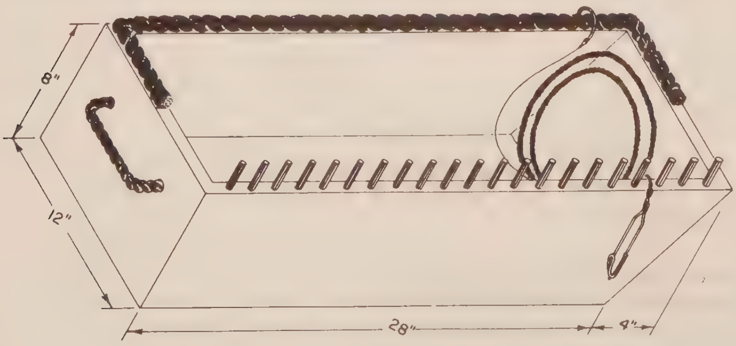

Fig. 5 - Dropper stowage box.

As the "D" rings pass through the hauler they are caught by one fisherman and threaded on the setting pin nearest the winch (see fig. 4). All rings for one basket are placed on a single pin and the cloverleaf knot marking the end of the basket is looped on top. The tub is then turned by hand until an alternate pin comes in line with the winch. (Rings of successive baskets are threaded on alternate pins to prevent lines from piling up too much in one place.) After the tub has made one complete revolution the process is repeated until three layers of 33 baskets each are in place. The tub is covered by a tarpaulin to keep the line from being disarranged before setting.

SETTING OPERATION: When setting the gear, the vessel is steered on a desired course at speeds up to nine knots. The tub is turned until the setting pin of the top basket lines up with the center of the setting trough. The end of the mainline is led through the setting trough. The floatline and buoy with pole are attached and the assembly is thrown overboard. Thereafter the drag of the end basket pulls the mainline from the tub.

The hook droppers are baited with sardines or herring. The AK snap, at the upper end of the dropper, is snapped on to the "D" ring without removing the "D" ring from its pin, and the dropper is then laid in the trough with the bait dangling overboard. The outgoing mainline snatches the ring and dropper from the pin and carries them overboard. Floatlines are snapped on in the same manner.

HAULING: The gear is hauled in the normal fashion by running the mainline through the longline hauler and into the tub. As the droppers come aboard, the winch is stopped momentarily and the snaps are removed from the "D" rings. The droppers are coiled and packed in specially designed plywood boxes (fig. 5). These have sloping ends to facilitate stowing the coils on edge. The hooks and snaps are secured to opposite sides of the box as shown. The "D" rings are threaded on pins as described before. Fish are gaffed and brought aboard through the gap in the rail shown in figure 2.

DISCUSSION

EVALUATION OF THE METHOD: Although still in the experimental stage, and with a great deal of developmental work yet to be done, the tub method appears to be commercially practicable. When employing the usual methods, POFI crews, consisting ordinarily of 11 men, fishing 60 to 100 baskets of gear, must break out, assemble, disassemble, and restow from 1 to 2 tons of wet line for each day's fishing. By eliminating the handling of the mainline, the size of the fishing crews may be reduced by more than one-half. Operation times for both methods are about the same, averaging about $3\frac{1}{2}$ minutes per basket for hauling gear and $2\frac{1}{2}$ minutes for setting. Thus, by this new method it would appear practicable for a small vessel, carrying 4 or 5 men, to fish 100 or more baskets of gear a day.

DEFECTS: It should be emphasized, however, that the method has only been tried experimentally and that additional testing and experience with the gear are necessary to insure satisfactory commercial application. Only a few defects in design have been noted so far, but these appear to be minor. One anticipated difficulty, that of fouling of the mainline in the tub during setting operations, failed to materialize. Indeed, less fouling by the tub method was experienced than when assembling and setting baskets by hand.

The most serious drawback noted so far is the excessive wear and tear on the mainline at the bridles caused by the impact of the "D" rings on rollers and longline hauler during hauling operations. In an effort to overcome this, the rollers have been made larger in diameter and the "D" rings have been reduced in size. To eliminate the difficulty altogether, a method of joining the droppers to the mainline by a system which swivels as freely as the "D" ring method, but which has less bulk, is needed.

Another defect of the present gear is that the knots which join the mainline sections abrade rapidly by passage through the haulers, so that the line at the knots needs recutting and splicing before the mainline itself is worn out.

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DISPLAY COPY

DESCRIPTION AND DISTRIBUTION OF LARVAE OF FOUR SPECIES OF TUNA IN CENTRAL PACIFIC WATERS

BY WALTER M. MATSUMOTO

FISHERY BULLETIN 128
From Fishery Bulletin of the Fish and Wildlife Service
VOLUME 58

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

UNITED STATES DEPARTMENT OF THE INTERIOR, Fred A. Seaton, *Secretary*
FISH AND WILDLIFE SERVICE, Arnie J. Suomela, *Commissioner*

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March 3, 1849

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VOLUME 58

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ABSTRACT

The larvae of four species of tuna—yellowfin (*Neothunnus macropterus*), skipjack (*Katsuwonus pelamis*), little tunny (*Euthynnus yaito*), and frigate mackerel (*Auxis thazard*)—are described in detail. Diagnostic characters are given to aid in the identification of the species.

The geographical and seasonal distributions of tuna larvae in equatorial waters from 1950 to 1952 are described. Yellowfin and skipjack larvae, which were the most abundant of the four species, were found to occur over a wide area between 23° N. and 15° S. latitude, from 120° W. to 180° longitude, the limits of the area investigated. The distribution was generally uniform over the entire area, but a slightly heavier concentration was noticed between 140° W. and 160° W. longitude from 5° S. to about 10° N. latitude. Although the geographical range has not been completely defined, the close adult-larva relationship points to a continuous transoceanic distribution along the equatorial currents. Both species appeared to be uniformly abundant throughout the year.

Nearly all the larvae were concentrated in the top 50 meters of water, with indications of a vertical, diurnal migration.

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DESCRIPTION AND DISTRIBUTION OF LARVAE OF FOUR SPECIES OF TUNA IN CENTRAL PACIFIC WATERS

By **WALTER M. MATSUMOTO**, ***Fishery Research Biologist***

BUREAU OF COMMERCIAL FISHERIES

The distribution of tuna larvae in the central Pacific is only one of several facets of an investigation of the life history, distribution, and abundance of tuna being undertaken by the Pacific Oceanic Fishery Investigations (POFI), of the United States Fish and Wildlife Service. The purpose of the present study is to identify and describe the tuna larvae found in these waters, to gain information on the location and time of spawning, and to obtain another measure of the comparative magnitude of the adult populations of the different species.

While it would have been logical and desirable to study the early life history of the tunas, beginning with the eggs, it was not possible to do so, since there were no discernible differences between the eggs of one species of tuna and those of another. All the ripe or near-ripe eggs examined from known species appeared alike (all had an opaque yolk mass and a distinctly noticeable oil droplet), and the range of egg diameter measurements for any one species overlapped that of the others. Consequently, no detailed work was done on their identification.

This paper presents comparative descriptions, based on material from zooplankton hauls, of the larvae of four species of tuna: yellowfin, *Neothunnus macropterus* (Temminck and Schlegel); skipjack, *Katsuwonus pelamis* (Linnaeus); little tunny, *Euthynnus yaito* Kishinouye; and frigate mackerel, *Auxis thazard* (Lacépède). The collections are sufficiently complete to enable us to trace the several species from early through late larval stages. The report also contains discussions of the horizontal and vertical distribution of these larvae, the diurnal variation and species composition of the larval catches, and estimations of the spawning area and time of spawning as evidenced by the development and distribution of the larvae.

The zooplankton samples from which the tuna larvae were collected were obtained from two main areas, equatorial waters and Hawaiian waters, during the years 1950 to 1952 on eight cruises of the POFI research vessel *Hugh M. Smith*. General station positions are shown in figures 1 and 2 (data on larvae collections for all the cruises are compiled in appendix tables 1 to 8, pp. 67–72). Samples were taken in 1-meter nets (*see* King and Demond, 1953, for detailed description), hauled according to two different methods. The first method was a 1-hour horizontal haul in which three nets were towed simultaneously at three different depths. The second method was a 30-minute oblique haul, a single open net being lowered to a depth of 200 meters and raised to the surface in a continuous operation.

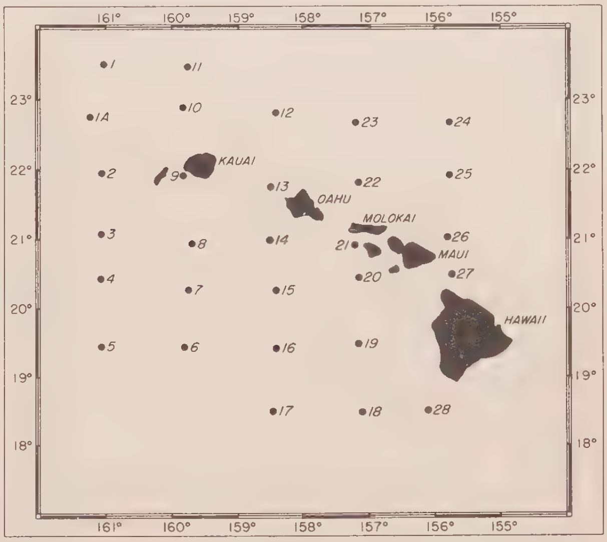

FIGURE 1.—Station locations of the *Hugh M. Smith* during cruise 6 in Hawaiian waters

In addition to the material collected by POFI, about 100 specimens of *E. yaito* and over 500 specimens of *A. thazard* taken in waters of the

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NOTE.—Approved for publication, February 26, 1957. Fishery Bulletin 128.

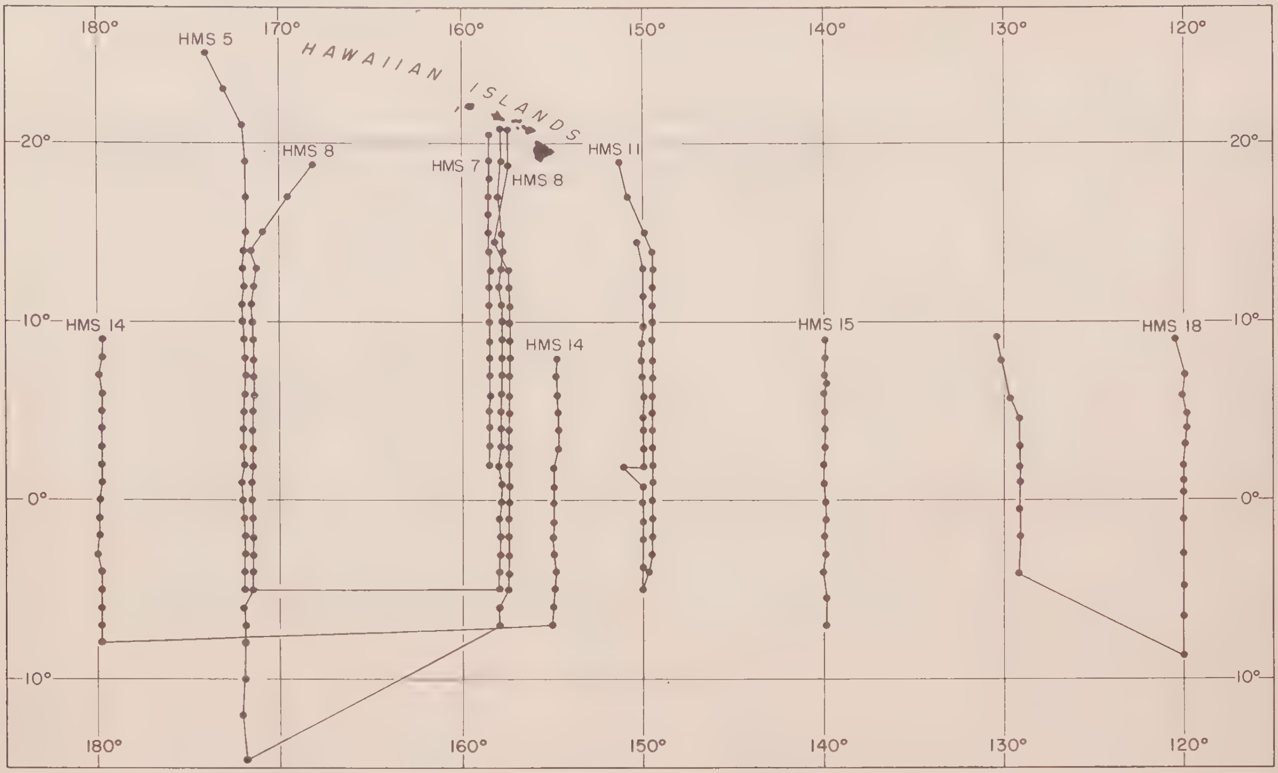

FIGURE 2.—Station locations of the *Hugh M. Smith* in equatorial waters.

East Indies during the 1928–30 *Dana* Expedition were examined.

The author wishes to thank the many POFI staff members who assisted in sorting the fish larvae from plankton samples, Wilvan Van Campen for numerous translations of literature in the Italian and Japanese languages, Tamotsu Nakata for drafting the charts in the text and for his advice on the reproduction of the drawings of tuna larvae, and the various staff members who critically reviewed the manuscript. Special thanks go to Dr. Å. Vedel Tåning, through whose kindness it was possible for us to examine the larval tunas collected during the 1928–30 *Dana* Expedition; to Dr. Milner B. Schaefer, Director of the Inter-American Tropical Tuna Commission, for the loan of juvenile *A. thazard*; to the California Division of Fish and Game for the loan of juvenile *E. lineatus*; to the Gulf Fishery Investigations for the loan of juvenile *E. alletteratus*; and to Dr. E. H. Ahlstrom, South Pacific Fishery Investigations, U. S. Fish and Wildlife Service, for his helpful criticisms and suggestions on the drawings of the larvae.

DESCRIPTION OF SPECIES

While there have been several valuable contributions to the identification of juvenile tunas, very little has been done on the identification of the larvae. The two most complete studies to date are those by Ehrenbaum (1924) and Wade (1951). Ehrenbaum examined larvae collected on the Danish oceanographical expeditions of 1908–10 to the Mediterranean and adjacent seas. The lack of juveniles in his collections did not permit him to make positive species identifications, and although his work has been cited in this paper as a general reference, for the most part his identifications have not been followed. Wade studied the larvae taken from waters around the Philippine Islands and was successful in collecting larval as well as juvenile specimens of *N. macropterus*, *K. pelamis*, and *E. yaito* (Wade 1950). His collections came from an area where adults of five species of Scombridae had previously been recorded [i. e., *Thunnus orientalis*, *T. germo* (=*Germo alalunga*), *Parathunnus mebachi* (=*P. sibi*), *Kishinoella tonggol*, and *N. macropterus*]. While there is good reason to believe that Wade's designation of certain larvae as *N. macropterus* is valid, some doubt exists as to his identification of *E. yaito*.

Prior to Wade's work, Schaefer and Marr (1948a, 1948b) had studied larval and juvenile stages of *N. macropterus*, *K. pelamis*, *E. lineatus*, and *A. thazard* taken off the Pacific coast of Central America. They had no difficulty in identifying the last three species. Regarding the first, their material came from an area where *P. sibi* is relatively scarce and their larger specimens showed anatomical characters that distinguish *N. macropterus*. However, these authors admitted the possibility that the smaller specimens were *P. mebachi* (=*P. sibi*), since identification could not be certain until juveniles of both species were available.

Our *N. macropterus* larvae resembled those examined by Wade and fitted nicely into the series of juveniles collected by Schaefer and Marr. Since ripe or nearly ripe gonads have been taken from adult *P. sibi* in equatorial waters (Yuen 1955), there is a possibility that some of the larvae could also be the young of *P. sibi*. While all indications seem to favor their being *N. macropterus*, final identification must wait until larvae and juveniles of *G. alalunga*, *P. sibi*, and some of the other scombrids have been caught and identified.

A situation somewhat comparable to that obtaining for *Neothunnus-Parathunnus* also exists for the species of *Auxis* discussed here. As pointed out by Wade (1949), the Philippine and East Indian regions have two species of this genus, *A. thazard* and *A. tapeinosoma*, these being rather easily separated as adults but much less so as juveniles. Apparently, only *thazard* occurs in the Hawaiian area,[1] and Hawaiian *Auxis* larvae are accordingly referred to this species. Because the present study also includes East Indian material, the possibility exists that specimens from that area may represent two species even though all material examined appeared identical with the Hawaiian *thazard*. There was no great difficulty in identifying larvae of *K. pelamis* and *E. yaito*.

In this section the detailed description of the smallest recognized specimen is given first. Descriptions of larger specimens follow in size sequence, and only the more prominent characters are noted. Finally, the distinctive characters or combinations of characters by which these species can be separated are discussed. The scheme of describing each specimen in its entirety, instead of following the development of certain anatomical characters throughout the size categories, was chosen because it seemed that this method would be more convenient for the reader. All descriptions and counts of the teeth and chromatophores on the head and body, unless specified otherwise, are based on one lateral half of the body, usually the left.

The smaller specimens were still in the initial stages of development and lacked many of the characters by which the adults are identified. They were separated into species by first segregating those larvae that were similar in appearance and then arranging them in a series according to size. From each series several specimens of various sizes were stained with alizarin according to the method described by Lipman (1935). The larger specimens in these series were more than 10 millimeters fork length and already possessed sufficient adult characters to permit positive identification. The more prominent and persistent characters, other than those used in identifying the larger specimens, were examined and traced down to the smallest individual in each series. The most useful of these characters are listed in tables 4 and 5 (pp. 53, 54). The six measurements used in tables 4 and 5 are defined as follows:

1. Total length: The distance from the tip of the upper jaw to the end of the longest caudal ray when the tail is not forked, and to the end of the middle caudal ray when the tail is forked.
2. Head length: The distance from the tip of the upper jaw to the posttemporal spine when the spine is present, and to the posterior margin of the head at the level of the vertebral column when the posttemporal spine is absent.
3. Mouth length: The distance from the tip of the upper jaw to the middle of the posterior edge of the maxillary, with the mouth closed or agape, varying with the specimen.
4. Snout length: The distance from the tip of the upper jaw to the anterior edge of the orbit.
5. Diameter of orbit: The diameter of the eye socket taken parallel to the body axis.

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[1] After this paper was submitted for publication, 21 specimens of long-corseletted *Auxis*, probably *A. tapeinosoma*, were taken about 1 mile offshore from the Island of Lanai in the Hawaiian Islands, November 30, 1957, by the Fish and Wildlife Service research vessel, the *John R. Manning*. This is the first record of the capture of long-corseletted *Auxis* in Hawaiian waters. Inasmuch as the waters around these islands have been subjected to rather intense tuna fishing since the turn of the century and a careful check has been kept of the local fish markets for a form of *Auxis* other than *thazard* for the past 8 or 9 years, we believe that the long-corseletted form occurs very rarely in local waters and that its recent appearance may be due to unusual oceanographic conditions. In our opinion, its discovery does not materially change the larval identification presented here.

6. Dorsal interspace: The distance between the insertion of the first dorsal fin and the origin of the second dorsal.
7. Tooth counts: Counts given for one side only.

In general, tuna larvae are characterized by a compact, triangular visceral mass with a short intestine that is directed ventrally at its posterior end. The entire visceral mass is located well forward in the body, the preanal distance being less than one-half the total body length on specimens up to about 9 mm. A continuous median fin membrane starts at the nape and extends completely around the caudal region to the anal opening. The myomeres, when distinct, number between 38 and 42. The head, mouth, teeth, and eyes are well developed, and prominent preopercular spines are noticeable. Pigmentation is rather sparse, most of it being concentrated over the abdominal sac, over the brain, and in the caudal region, depending on the species.

As an aid in comparing the differences between larvae of various species and at different stages of development, the following summary of the key characters is presented in advance of the detailed descriptions, together with a sketch of a typical tuna larva (fig. 3) in which is incorporated the nomenclature used in this paper.

Neothunnus macropterus

a. Complete lack of chromatophores on the trunk, except over visceral mass, until the larva approaches 14 mm. total length.
b. No chromatophores over the forebrain.
c. Heavy pigmentation on the first dorsal fin in specimens of more than 7 mm.

Katsuwonus pelamis

a. Presence of a distinct chromatophore on the ventral midline of the caudal region.
b. Early appearance of chromatophores over the forebrain in specimens of more than 7 mm. total length.
c. Single chromatophore on middle of mandible in specimens of more than 7 mm.
d. Chromatophores only along outer edge of first dorsal fin.

Euthynnus yaito

a. Up to 4 chromatophores along the posterior base of the anal fin and the first 2 or 3 anal finlets. No chromatophores along the dorsal margin of the caudal region.
b. Series of chromatophores along the mandible, usually extending over the anterior half.
c. Heavily pigmented first dorsal fin.
d. Chromatophore usually present at the symphysis of the pectoral girdle.

Auxis thazard

a. A short series of closely spaced chromatophores on the middorsal, midlateral, and midventral lines of the caudal region.
b. Lower jaw free from pigmentation, except at the tip.
c. First dorsal fin relatively unpigmented, with 3 or less chromatophores at about 12 mm. in total length.
d. Chromatophore usually present at the symphysis of the pectoral girdle.

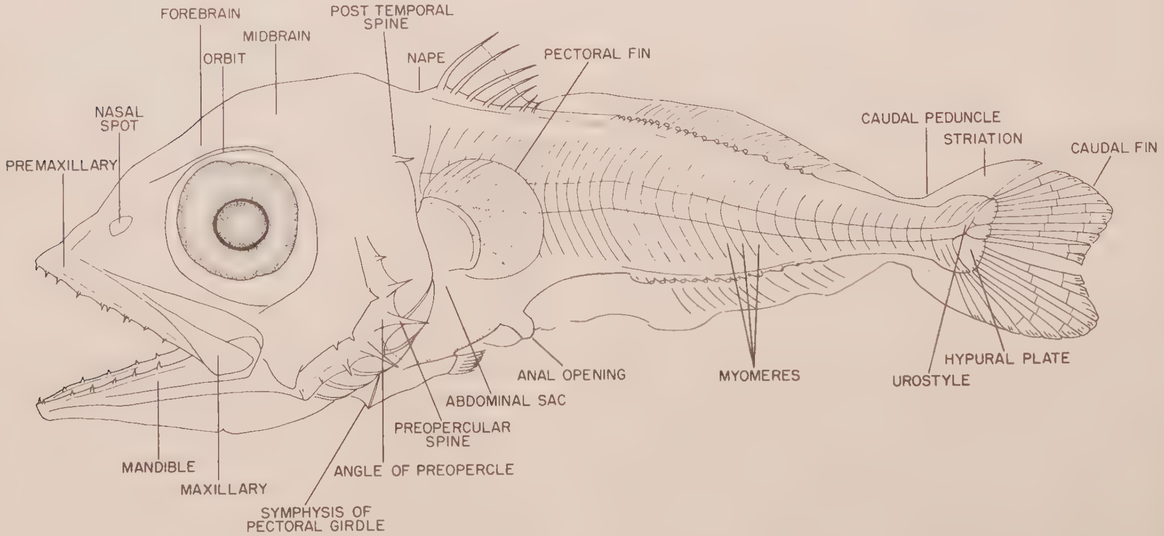

FIGURE 3.—A typical tuna larva with the nomenclature employed for various parts of the body.

YELLOWFIN (*NEOTHUNNUS MACROPTERUS*)

The description of this species is based on a study of 264 specimens, whose total lengths range from less than 3.0 mm. to 14.2 mm. (table 1). While the specimens less than 3.9 mm. in length could not be identified positively, they so closely resemble the smallest larva identified as *N. macropterus* that they are included in the total.

The smallest specimen identified as *N. macropterus* measures 3.9 mm. (fig. 4) and has about 40 myomeres. The body is evenly tapered caudally, and the abdominal sac is roundly triangular with the anal region directed sharply downward. The anal opening is well ahead of the midlength of the body. The snout on this specimen is slightly distorted, and no comparison of the head parts involving snout measurements has been attempted, although it is evident that the snout is only slightly longer than half the diameter of the orbit. No teeth are observable on this specimen, but other specimens of about the same length show up to 3 feeble teeth on each ramus of both jaws. Three spines project posteriorly along the edge of the preopercle, the middle one being the longest, and 2 minute spines are present on the surface of the preopercle just anterior to the preopercular spines.

The unpaired fins are not developed, but are represented by a continuous membrane extending from the nape completely around the caudal end of the body to the anal opening. Membranous pectoral fins are present, but ventral fins are lacking.

TABLE 1.—*Number and size range of larval* Neothunnus macropterus *collected by the* Hugh M. Smith *in Hawaiian and equatorial waters*

[See figs. 1 and 2 for location of stations]

Cruise and station	Number of larvae	Size range (mm.)
HAWAIIAN WATERS:		
Cruise 6:		
No. 1	2	5. 3–6. 0
No. 1A	5	4. 4–6. 5
No. 2	13	3. 0–6. 0
No. 5	2	3. 5–4. 5
No. 6	2	3. 8–4. 2
No. 7	5	5. 4–8. 0
No. 8	1	4. 6
No. 10	12	3. 3–6. 1
No. 11	5	4. 0–6. 8
No. 13	6	4. 0–5. 6
No. 14	13	3. 6–6. 0
No. 15	7	4. 0–10. 2
No. 16	4	3. 5–5. 6
No. 18	16	3. 2–7. 5
No. 19	2	5. 2–6. 5
No. 21	8	3. 6–6. 5
No. 24	2	4. 6–7. 45
No. 25	15	3. 5–5. 6
No. 26	6	3. 0–3. 9
No. 27	6	2. 5(?)–6. 5
Total	132	2. 5(?)–10. 2
EQUATORIAL WATERS:		
Cruise 5:		
No. 8	1	3. 3
No. 12	1	4. 9
No. 13	2	<3. 0, 4. 2
No. 14	1	7. 0
No. 15	1	<3. 0
No. 17	1	<3. 0
No. 21	2	4. 4, 5. 2
No. 25	1	3. 8
No. 26	9	3. 2–4. 6
No. 39	1	6. 0
No. 41	1	4. 9
No. 42	2	4. 9, 5. 5
No. 43	1	5. 5
No. 45	1	3. 5
No. 48	2	3. 7, 4. 9
No. 51	3	3. 1–5. 2
Cruise 8:		
No. 9	2	6. 2, 7. 9
No. 16	1	5. 3
No. 21	1	3. 0
No. 22	1	<3. 0
No. 24	5	<3. 0–5. 6
No. 77	6	3. 5–4. 0
No. 78	4	<3. 0–4. 2
No. 79	2	4. 0, 5. 0
No. 82	1	14. 2
No. 85	1	4. 9
No. 93	1	6. 2
No. 94	1	4. 7
No. 97	1	5. 2
No. 101	1	3. 7
Cruise 11:		
No. 4	2	<3. 0, 4. 8
No. 6	2	5. 3
No. 8	4	3. 1–8. 0
No. 9	4	3. 2–5. 6
No. 10	2	3. 5, 3. 7
No. 11	7	<3. 0–6. 6
No. 12	2	5. 2, 6. 6
No. 22	3	3. 3–7. 1
No. 23	1	3. 0
No. 33	1	6. 0
No. 35	1	4. 0
No. 36	1	5. 9
No. 37	2	4. 5, 4. 6
No. 40	3	<3. 0–3. 8
No. 42	1	3. 8
No. 46	4	3. 0–3. 6
Cruise 14:		
No. 12	1	5. 0
No. 14	1	5. 0
No. 19	3	4. 0–4. 1
No. 20	1	7. 1
No. 21	2	3. 7, 4. 1
No. 22	1	3. 7
No. 30	4	3. 8–6. 4
No. 31	2	5. 7, 7. 8
No. 32	3	4. 6–7. 7
Cruise 15:		
No. 5	4	<3. 0–6. 0
No. 6	2	5. 0, 8. 1
No. 7	1	3. 0
No. 14	1	4. 5
No. 15	1	3. 2
No. 16	1	4. 1
Cruise 18:		
No. 4	2	3. 0, 3. 2
No. 5	2	3. 1, 3. 2
No. 6	1	3. 2
No. 8	1	4. 6
Total	132	<3. 0–14. 2

Head pigmentation is rather sparse, with only about 4 very small, scattered chromatophores over the membrane covering the brain and 2 internal

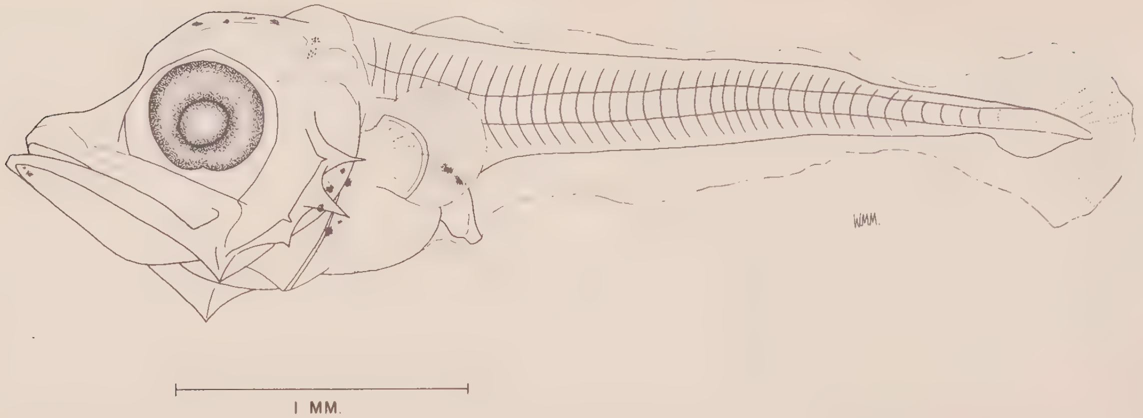

FIGURE 4.—*Neothunnus macropterus*, 3.9 mm. total length.

chromatophores along the posterior margin of the brain. Several large chromatophores are present over the anterior and posterior regions of the abdominal sac, but the rest of the body is free of pigmentation.

A specimen of 4.75 mm. has the same general appearance of the preceding stage, with 39 or 40 myomeres, but the body has deepened slightly. The teeth have increased to 5 on the upper jaw, but the 3 remain on the lower jaw. There is a slightly depressed, ovate, nasal spot on the snout which represents the future nostrils. The preopercular spines have increased to 4: 2 long spines at the angle and 2 small spines on the horizontal edge. There is no change in pigmentation, and the pelvic fins are just emerging as minute fleshy outgrowths from the ventral outline of the body beneath the abdominal sac.

Certain changes are evident in a 5.5-mm. specimen (fig. 5). The head appears slightly larger, 36.8 percent of the total length, and the snout, which is two-thirds the diameter of the orbit, is bluntly pointed. The mouth represents only 60.1 percent of the head length and all the teeth, 8 on the upper jaw and about 4 on the lower jaw, are small and feeble. Six preopercular spines are visible: 1 small spine on the vertical edge; 3 longer spines at the angle, the middle one being the longest; and 2 short spines on the horizontal edge.

The unpaired fins are still represented by a continuous membrane, which has degenerated in the region of the future first dorsal fin and appears slightly heavier there. The membrane also shows signs of degeneration in the region of the caudal peduncle, and about 10 incomplete rays are noticeable in the caudal fin. The pelvic fins are quite evident although they are still rudimentary.

The tips of both jaws bear several small chromatophores, and there are about 14 large chromatophores over the midbrain, although these

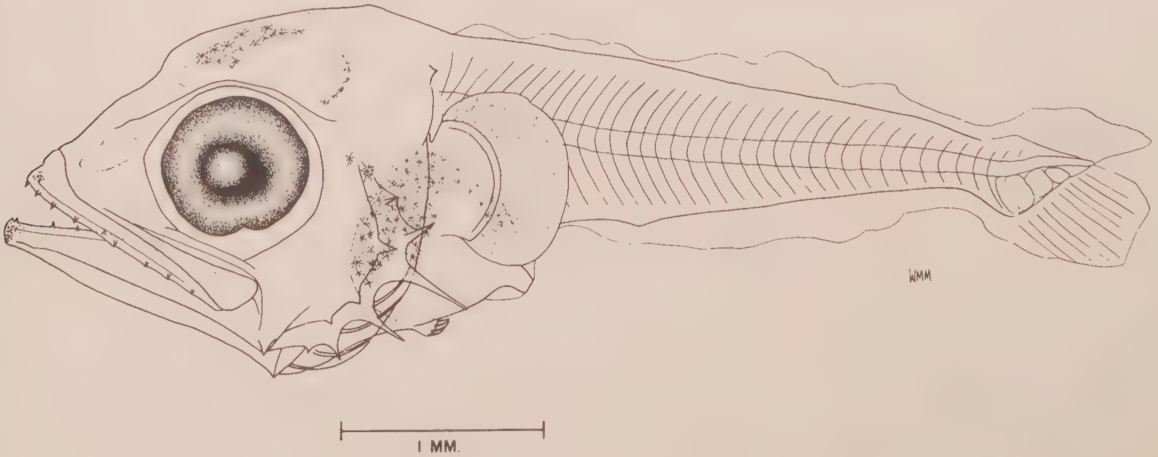

FIGURE 5.—*Neothunnus macropterus*, 5.5 mm. total length.

extend only over half of the brain area. A band of dark pigmentation lies along the posterior margin of the brain, and the 2 dermal chromatophores on the side of the head near the dorsal end of the preopercle make up the remainder of the pigmentation on the head. The dorsal half of the abdominal sac bears numerous large chromatophores, while the rest of the body is unpigmented.

Except for the appearance of 4 short spines in the first dorsal fin, about 12 rays in the caudal fin, and the formation of a very small spine near the posttemporal region, the specimen at 6.4 mm. (fig. 6) remains relatively the same in appearance as the previous one. There is a single, faint chromatophore on the third interradial membrane of the first dorsal fin, and the fin membrane here has degenerated to the height of the spines. The membrane is still high over the rest of the body.

At 7.15 mm. (fig. 7), the anal opening is closer to the midpoint of the body length. The snout is slightly longer, but is still not quite as long as the diameter of the orbit, and the nasal spot is beginning to constrict in the middle. The mouth is not very large and represents 62.1 percent of the head length. There are 10 or 11 small teeth on the maxillary and 6 or 7 similar teeth on the mandible.

The most noticeable development here is in the first dorsal fin, which bears 7 strong spines, the first 5 of them very long. About 19 rays are present in the caudal fin, which is just beginning to fork. The pelvic fins are only slightly larger than in the previous specimen.

There is an increase in the pigmentation over the brain, at the tips of both jaws, and over the abdominal sac. The band of pigment along the

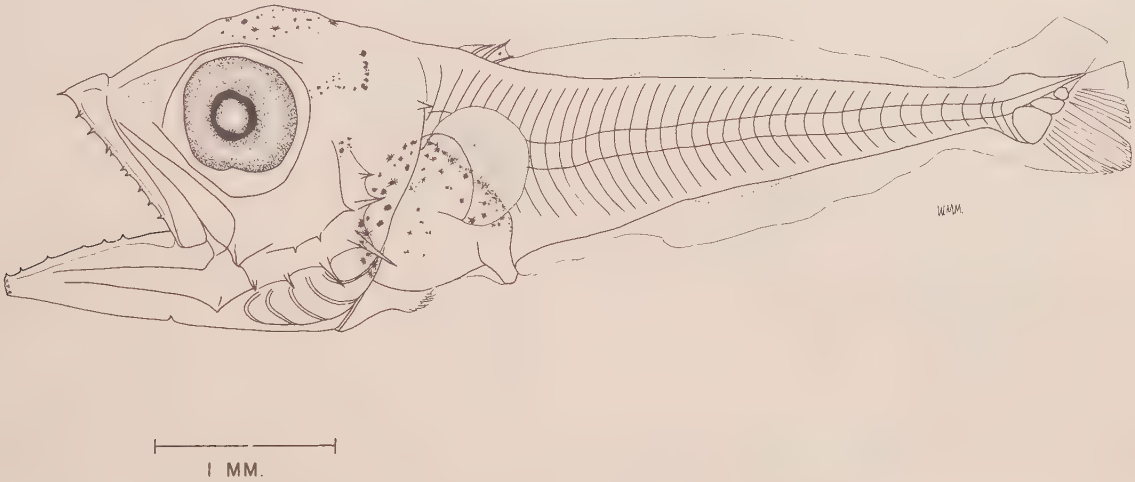

FIGURE 6.—*Neothunnus macropterus*, 6.4 mm. total length.

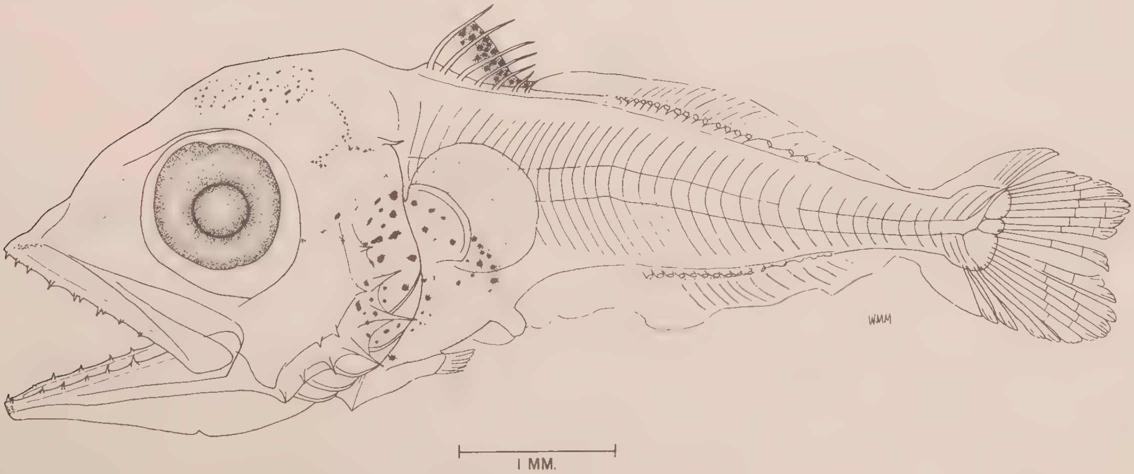

FIGURE 7.—*Neothunnus macropterus*, 7.15 mm. total length.

posteroventral margin of the brain and the chromatophores near the dorsal end of the preopercle have increased in number and are most noticeable. Two chromatophores are present near the posterior edge of the orbit, and the darkly pigmented distal half of the interradial membrane of the first dorsal fin is rather prominent.

Some interesting development is noted in a stained specimen of 7.45 mm. While many of the dermal bony structures have ossified, the anterior vertebrae are just in the process of ossification. The first six vertebrae appear as "rings" and each of them has a very large, complete neural arch. On succeeding vertebrae the areas of ossification diminish in size until only the bases of the neural and haemal arches and their corresponding spines are evident at about the 14th vertebra. Posteriorly, only the urostyle is completely ossified and the hypural plate is just beginning to ossify.

A 7.95-mm. specimen is shown in figure 8. The general shape of the body remains the same as in the preceding specimen. The more obvious developments are the almost complete separation of the nasal openings, the deeper fork of the caudal fin, and the darker and larger area of pigmentation on the first dorsal fin, which is now almost completely pigmented, except for a narrow strip near its base. About 9 to 10 teeth are present on each jaw and 3 teeth are noticeable on the palatine bone.

While both the dorsal and anal fin rays are represented only by striations, there are 13+13 caudal rays. The pelvic fins, although complete with 1 spine and 5 rays, are very short. The rays of the pectoral fins are not distinct and appear only as striations.

In a 9.2-mm. specimen there is no apparent change in the head size, which is 37.9 percent of the total length of the body (fig. 9). The anal opening is at the midpoint of the body length, and the snout appears longer, its length being about the same as or slightly greater than the diameter of the orbit. The nares are separate, and both upper and lower jaws bear 12 teeth, while the palatine bone has about 4 very small teeth. Seven preopercular spines are discernible: 2 spines on the vertical edge, 2 spines at the angle, and 3 spines on the horizontal edge.

The first dorsal fin has 10 spines and a slightly convex outline. The rays of the second dorsal fin are not clearly defined and no accurate count could be made. There appear to be about 6 or 7 dorsal "finlets" and the anal fin has about 14 rays and 7 finlets, though the finlets are not completely formed and none of them is definitely separated from the others. The caudal fin has 14+15 rays, and the depth of the fork is about one-third the length of the longest caudal fin ray. The pelvic fins have the full adult complement of spines and rays, the longest of which are nearly as long as the longest spine of the first dorsal fin.

A stained specimen of 10.2 mm. shows 13 completely ossified vertebrae, and 13 more which are only partly ossified. The first haemapophysis appears on the 8th vertebra, and closed haemal arches are present only on the 11th, 12th, and 13th vertebrae. On the 12-mm., stained speci-

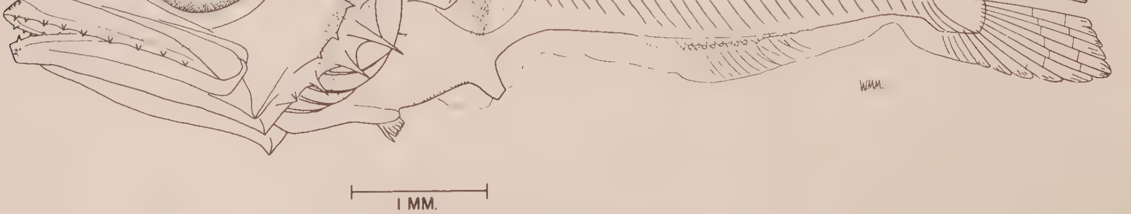

FIGURE 8.—*Neothunnus macropterus*, 7.95 mm. total length.

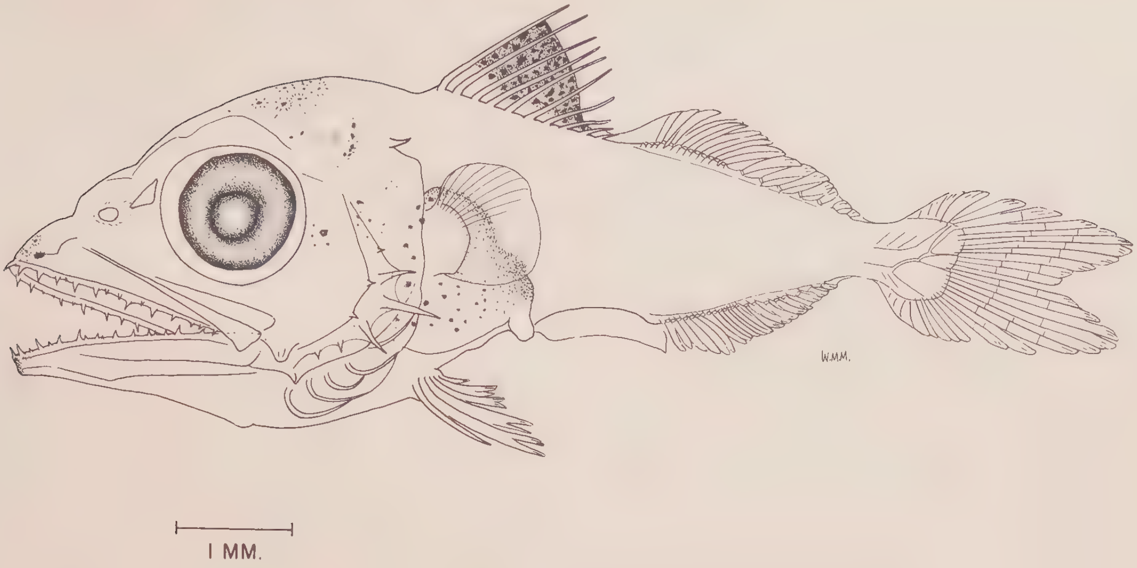

FIGURE 9.—*Neothunnus macropterus*, 9.2 mm. total length.

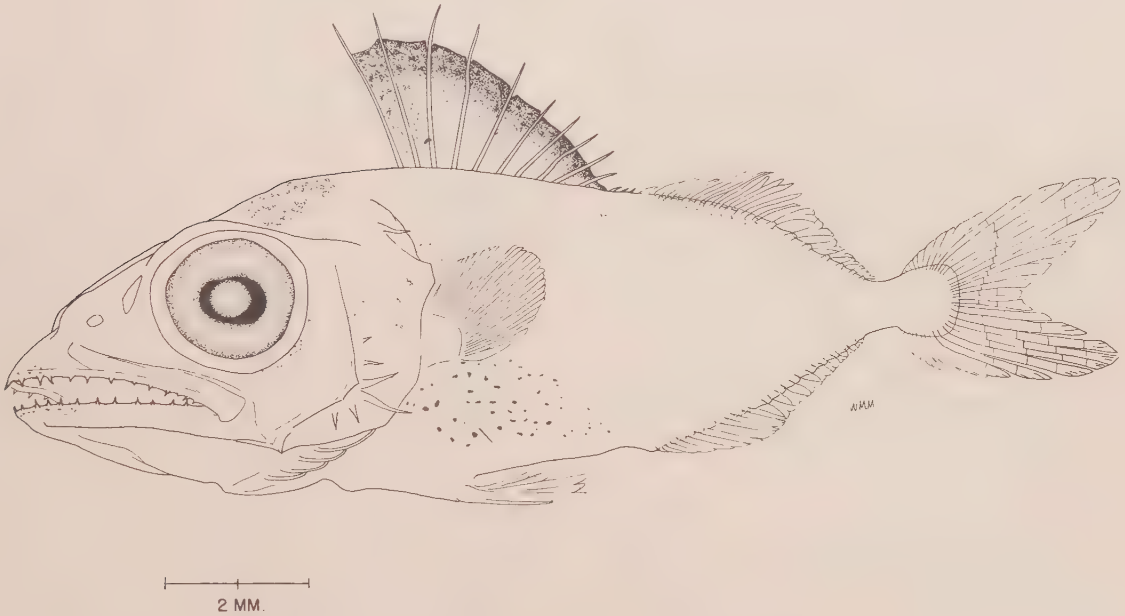

FIGURE 10.—*Neothunnus macropterus*, 14.25 mm. total length.

men all of the vertebrae are ossified, and they number 18 precaudals and 20 caudals, including the urostyle. The first few vertebrae are beginning to assume the hourglass shape of the adult centrum. The haemal arches are narrow, none of them being as wide as the diameter of the centrum at this stage of development.

At 14.25 mm. (fig. 10) the body is much deeper, especially near the insertions of the second dorsal and anal fins. The triangular abdominal sac is large and elongate, and the anal opening is just anterior to the insertion of the anal fin.

The head, which is 39.7 percent of the total body length, appears very large, and the length of the snout is equal to the diameter of the orbit. The nares are well separated, the round, anterior naris being about one-third the size of the nearly elliptical, posterior one. About 13 or 14 teeth are noticeable on both the upper and lower jaws in the unstained specimen. Six preopercular spines are visible, but only the 2 longest ones at the angle still project free from the preopercular bone.

The first dorsal fin is composed of 14 spines and the fin outline appears slightly convex. Both the second dorsal and anal fins consist of 15 rays and 8 finlets. There are about 18+19 rays in the caudal fin, but those near the anterior edges are not clear enough to be counted accurately. The pelvic fin is very large and is almost as long as the pectoral fin, which now bears about 30 rays.

Pigmentation is beginning to resemble that of juveniles. The large chromatophores over the brain still extend over a relatively small area, but numerous, very minute chromatophores appear over the posterior part of the head and extend posteriorly in a band to a point beneath the insertion of the second dorsal fin. There is a patch of similar pigmentation immediately behind the opercle and dorsal to the pectoral-fin insertion. Small chromatophores also line the posteroventral margin of the orbit, while 5 to 6 large chromatophores are present on the surface of the opercle posterior to the eye. Pigmentation over the abdominal sac remains unchanged, while the first dorsal fin is now completely pigmented. A faint line of chromatophores is present along the bases of the first and second dorsal fins, extending posteriorly to about the second dorsal finlet. The rest of the body has no pigmentation.

SKIPJACK (*KATSUWONUS PELAMIS*)

A total of 476 specimens of *K. pelamis* measuring from 2.3 mm. to 20.1 mm. was sorted from plankton collections and examined (table 2). Also studied were 34 specimens from 20.0 mm. to 43.0 mm. collected with dip net at night-light stations in Kingman Reef lagoon in May 1951.

The smallest specimen that could be identified positively as *K. pelamis* measures 3.7 mm. in length (fig. 11); this specimen appears somewhat distorted in preservative. The body is elongate with both the dorsal and ventral outlines tapering evenly to the caudal end. The abdominal sac is roundly triangular in shape with the anal opening slightly anterior to the midpoint of the total length of the body.

Although the snouts on other specimens of comparable size are rather pointed, this is not evident here, probably because of distortion. The upper

TABLE 2.—*Number and size range of larval* Katsuwonus pelamis *collected by the* Hugh M. Smith *in Hawaiian and equatorial waters*

[See figs. 1 and 2 for locations of stations]

Cruise and station	Number of larvae	Size range (mm.)
HAWAIIAN WATERS:		
Cruise 6:		
No. 1	1	6.0
No. 1A	11	4.4–7.0
No. 2	4	4.0–6.0
No. 4	10	3.5–4.5
No. 5	14	3.6–5.5
No. 7	4	4.5–6.5
No. 8	9	3.5–8.5
No. 10	29	2.5 (?)–7.55
No. 11	9	4.1–7.65
No. 13	12	4.0–5.6
No. 15	13	3.2–6.5
No. 16	6	?–8.0
No. 18	27	3.6–8.8
No. 19	3	9.85–12.5
No. 20	2	3.6, 5.0
No. 22	2	4.0, 6.6
No. 24	3	6.2–8.8
No. 25	1	3.7
No. 27	4	3.5–3.7
Total	164	2.5–12.5
EQUATORIAL WATERS:		
Cruise 5:		
No. 2	1	4.5
No. 4	3	3.4–3.6
No. 11	3	4.6–5.0
No. 14	4	3.5–6.1
No. 16	2	9.1, 10.1
No. 19	1	3.8
No. 21	1	4.0
No. 22	8	3.5–8.8
No. 23	24	3.2–6.9
No. 25	17	2.7–4.9
No. 26	2	6.8, 10.0
No. 32	1	4.6
No. 35	1	7.0
No. 36	6	2.9–4.5
No. 37	6	3.3–8.0
No. 38	1	4.6
No. 42	1	6.5
No. 43	2	Distorted.
No. 45	4	3.1–4.0
No. 46	1	4.5
No. 51	2	3.6, 4.6
Cruise 8:		
No. 11	3	4.6–5.6
No. 20	1	7.2
No. 25	2	2.8, 3.0
No. 77	9	3.0–5.4
No. 78	2	4.0, 4.6
No. 79	5	4.1–6.1
No. 80	2	2.5, 5.0
No. 81	2	4.0, 4.2
No. 84	4	5.1–20.1
No. 85	1	3.6
No. 87	1	3.0
No. 88	1	3.0
No. 89	1	3.7
No. 90	8	5.0–6.5
No. 91	3	2.7–6.5
No. 93	1	8.1
No. 94	1	4.0
No. 95	2	5.0, 8.0
Cruise 11:		
No. 1	1	3.6
No. 6	1	5.0
No. 9	1	9.4
No. 10	1	3.1
No. 11	6	2.9–12.6
No. 12	1	6.7
No. 22	2	3.9, 8.0
No. 23	1	5.0
No. 24	2	5.5, 14.9
No. 26	2	6.5
No. 27	3	3.5–5.1
No. 29	21	3.8–6.5
No. 31	7	3.0–8.0
No. 33	1	4.1
No. 36	1	10.9
No. 37	3	3.4–6.3
No. 38	1	6.6
No. 41	1	3.9
No. 42	1	6.1
No. 43	1	4.2

TABLE 2.—*Number and size range of larval* Katsuwonus pelamis *collected by the* Hugh M. Smith *in Hawaiian and equatorial waters*—(Continued)

[See figs. 1 and 2 for location of stations]

Cruise and station	Number of larvae	Size range (mm.)
EQUATORIAL WATERS—Continued		
Cruise 14:		
No. 2	9	3.5–6.0
No. 4	1	3.1
No. 7	1	3.3
No. 8	1	3.0
No. 9	14	3.4–10.3
No. 10	2	5.0, 7.0
No. 12	4	5.0–9.4
No. 14	3	2.3–6.0
No. 17	2	4.2, 9.0
No. 18	3	3.5–5.6
No. 20	7	4.0–6.2
No. 21	8	4.0–4.6
No. 22	2	3.5, 4.5
No. 24	1	3.7
No. 25	2	3.0
No. 29	4	3.2–5.0
No. 30	4	3.5–6.5
No. 32	1	4.0
Cruise 15:		
No. 6	7	3.2–6.5
No. 7	10	3.2–7.5
No. 8	10	3.1–5.0
No. 9	8	2.7–5.9
No. 10	1	19.0
No. 14	3	3.2–4.2
No. 15	1	3.6
No. 17	1	4.5
Cruise 18:		
No. 5	1	4.5
No. 6	1	10.1
No. 21	1	5.0+(distorted).
No. 24	1	5.4
Total	312	2.3–20.1

and lower jaws contain 4 and 6 teeth, respectively, and there are 3 spines along the edge of the preopercle, the middle one being the longest. The pectoral fins are present, but are represented only by a thin membrane, while the pelvic fins are completely absent. The median fins are represented by a continuous membrane which begins at the nape and continues around the caudal end to the anal opening. No fin rays are developed, but a few faint striations can be seen in the caudal region.

Most of the pigmentation is subcutaneous. About 10 small chromatophores are scattered over a fairly large portion of the membrane covering the midbrain. The dorsal edge of the abdominal sac is pigmented with very small chromatophores, while a very large one is evident on the anterior edge. A single chromatophore is present along the midventral line at about the 34th myomere. In all specimens examined the presence of this chromatophore is extremely consistent, although sometimes 2 or 3 replace the usual 1. The only dermal pigmentation on this specimen occurs at the tip of the lower jaw, where 2 to 3 small chromatophores are noticeable.

A specimen of 5.35 mm. (fig. 12) shows some advances in development. The head, representing 38.7 percent of the total length, is very large in relation to the rest of the body, and the sharply pointed snout is slightly longer than the diameter of the orbit. The length of the mouth is equivalent to 71.6 percent of the head length, and is much larger than that of *N. macropterus* of a comparable size. The teeth, 13 on the upper and 11 on the lower jaw, are well developed, and 6 spines are present along the edge of the preopercle. The pigmentation is now more extensive and covers more than half the area of the midbrain. The pelvic fins are seen only as small buds. No vertebrae are formed as yet and myomeres are only faintly visible. They number either 41 or 42.

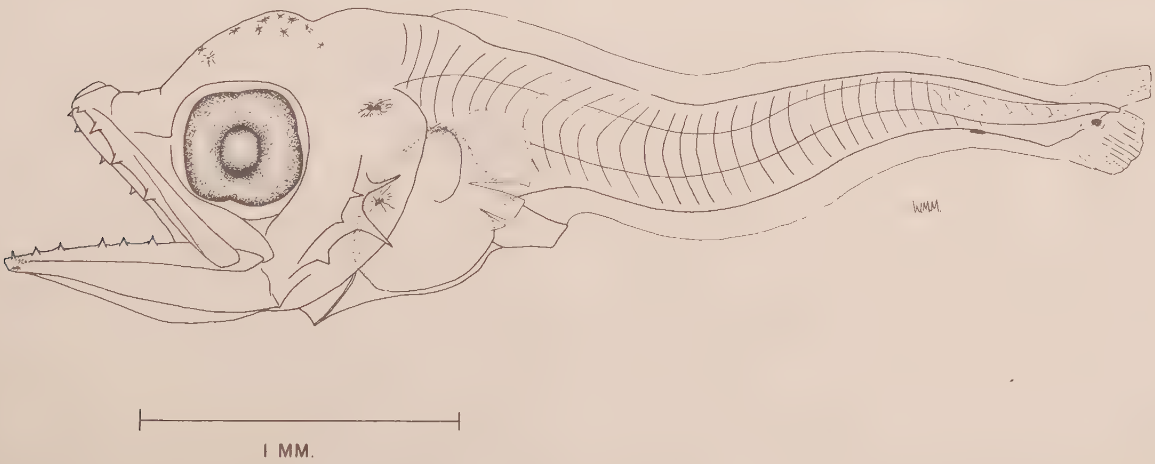

FIGURE 11.—*Katsuwonus pelamis*, 3.7 mm. total length.

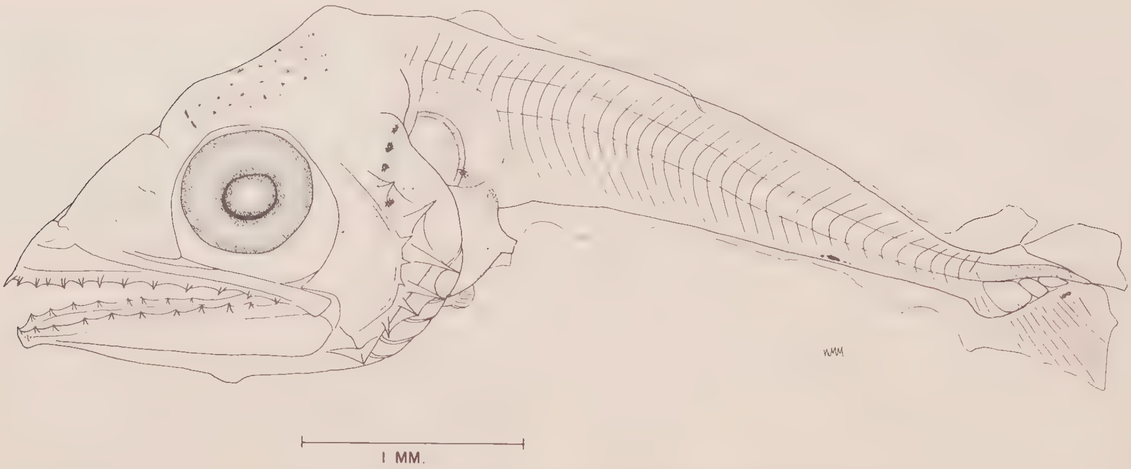

FIGURE 12.—*Katsuwonus pelamis*, 5.35 mm. total length.

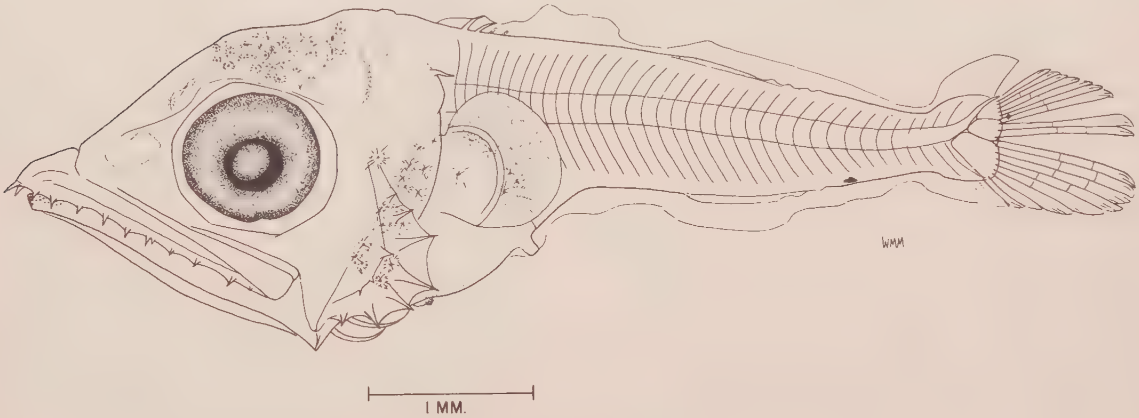

FIGURE 13.—*Katsuwonus pelamis*, 6.7 mm. total length.

The beginnings of the hypural plates are present, and the urostyle has developed and is turned upward.

The greatest change in a 6.7-mm. specimen (fig. 13) is in the first dorsal fin, where 4 spines have developed, the first 2 being very distinct. The only fin showing further development is the caudal, which now contains 18 rays. The urostyle is turned upward and the hypural plates are in a more terminal position. These bones are not yet ossified and do not take a stain.

The number of chromatophores over the midbrain has increased to about 33, and 2 closely set chromatophores are present over the forebrain, well ahead of the main, pigmented area. One or 2 large, dermal chromatophores appear on the side of the head near the dorsal end of the preopercle, while the pigmentation on the abdominal sac shows only a slight increase. No change is shown by the single chromatophore on the midventral line of the caudal region, or in the 41 myomeres.

At 7.1 mm. (fig. 14), the body is very much deeper and the head, composing 43.2 percent of the total length of the body, is still large. The snout length is almost equal to the diameter of the orbit. Eight short spines are present in the first dorsal fin, and the fin rays and finlets of the second dorsal and anal fins are beginning to develop. These appear only as striations in the membrane and cannot be counted accurately. The membrane between the first and second dorsal fins is beginning to degenerate, and there are about 12+11 rays in the caudal fin, the posterior edge of which has just begun to fork.

Pigmentation over the brain is similar to that on the previous specimen, but it extends over almost the entire midbrain area. Two additional chromatophores appear: a small one on the lower jaw, at about one-fourth of the jaw length posterior to the tip, and another on the first dorsal fin at the outer edge of the second interradial membrane.

Several noticeable changes have taken place by the time the species has reached a length of 8.75 mm. (fig. 15). The anal opening is now slightly posterior to the midpoint of the total length of the body. The head is still large, 41.3 percent of the total length, and the snout, which is nearly equal to the diameter of the orbit, is sharply pointed. The growth across the nasal opening is complete, thus forming 2 openings. The mouth is large and represents 66.0 percent of the head length. There are 16 to 18 teeth on both jaws and about 5 on the palatine bone.

Eight or 9 spines are present in the first dorsal fin and, while their number does not differ appreciably from that in the 7.1-mm. specimen, they are nearly twice as long. There are about 10 rays and 6 or 7 finlets in both the second dorsal and anal fins. The pelvic fins are well developed, with 1 spine and 5 rays, while the pectoral fins are only striated.

Changes in pigmentation consist of the appearance of a few more chromatophores over various parts of the body. Several dark chromatophores are scattered on the tip of the snout, and the chromatophore on the lower jaw has moved back

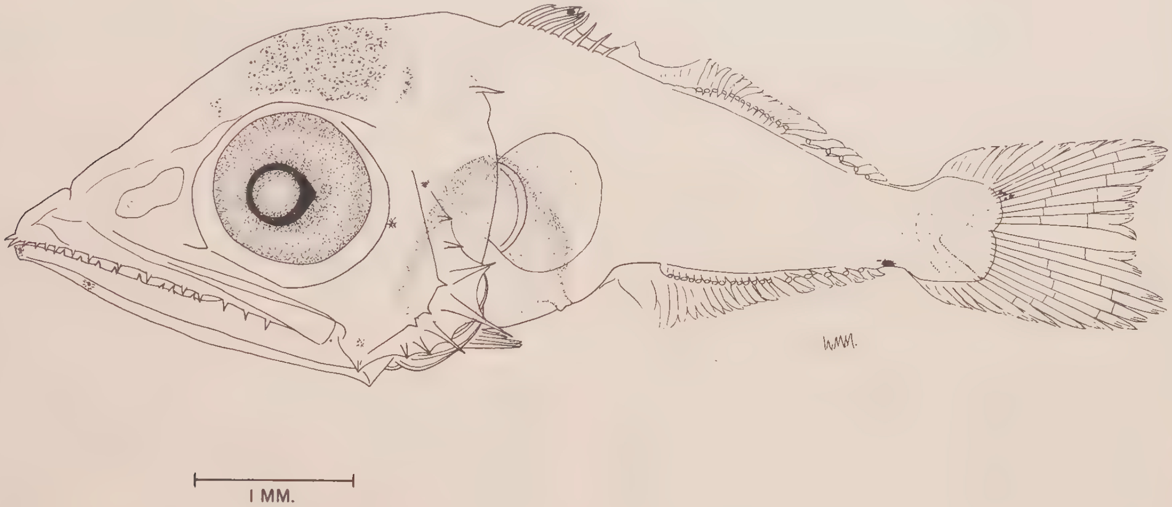

Figure 14.—*Katsuwonus pelamis*, 7.1 mm. total length.

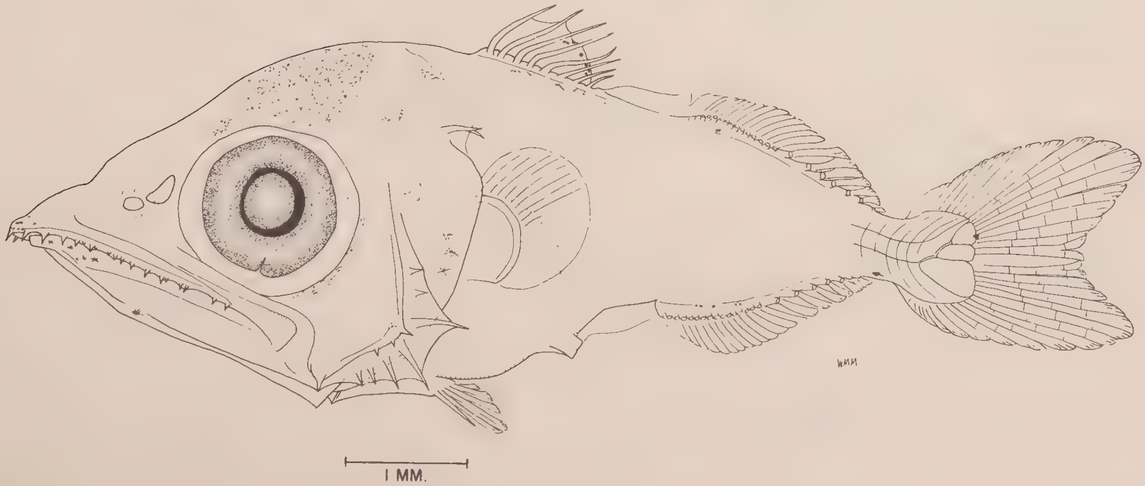

Figure 15.—*Katsuwonus pelamis*, 8.75 mm. total length.

to about one-half the length of the mandible. The posteroventral edge of the orbit is lined with about 10 small chromatophores, and about 6 fairly large, faint chromatophores are present on the preopercular surface posterior to the eye. Three or 4 small chromatophores also are noticeable in the posttemporal region, while 6 to 8 chromatophores appear along the base of the first dorsal fin and 1 near the second dorsal fin insertion. The outer edges of the 3d through the 6th interradial membranes of the first dorsal fin are pigmented with about 6 large chromatophores. Three chromatophores are also present along the base of the anal fin.

Rapid vertebral development has occurred between the 8.0-mm. and the 8.8-mm. specimens, both of which were stained. Only the urostyle is ossified on the smaller specimen, while the larger one shows complete ossification of the urostyle and the first 11 vertebrae. The first haemapophysis occurs on the 9th vertebra and the first closed haemal arch on the 11th.

Very definite changes are seen in a 10.9-mm. specimen (fig. 16). The abdominal sac is still roughly triangular, but the anal opening has moved back toward the anal-fin insertion. The nostrils are farther apart and, while the posterior one is still elliptical in shape, the anterior one is now smaller and more circular.

There are 9 preopercular spines: 4 small spines on the horizontal edge, 3 short spines on the vertical edge, and 2 very long spines at the angle. All of these, with the exception of the 2 long ones at the angle, are completely overgrown by the preopercular bone.

Fin development shows the greatest changes. There are 13 definite spines in the first dorsal, about 15 rays plus 8 finlets in the second dorsal, and about 14 rays plus 7 finlets in the anal fin. However, differentiation between the last fin ray and the first finlet is not clearly defined. The caudal fin rays number 16+16, and the pelvic fins show the full complement of 1 spine and 5 rays.

There is an increase in the number of chromatophores over the brain, at the tips of both jaws, and along the posteroventral margin of the orbit. The area posterior to the brain between the posttemporal spine and the dorsal edge of the body bears numerous small chromatophores, which extend backward along the dorsal margin of the body and gradually disappear near the base of the first dorsal finlet. Four small chromatophores are present along the base of the anal fin, and the single, dark chromatophore still persists on the ventral midline of the caudal peduncle. Six large chromatophores appear on the midlateral line of the body between verticals through the second dorsal insertion and the first dorsal finlet.

The vertebral count on a stained specimen of 9.85 mm. is 20 precaudal plus 21 caudal vertebrae, including the urostyle. All of the vertebrae are completely ossified, but none of the centra shows the typical hourglass shape of the adult. The first haemapophysis is on the 9th vertebra, and the first closed haemal arch is on the 11th. There are no inferior foramina along the vertebral column at this stage of development.

At 14.5 mm. (fig. 17), the body does not appear to be quite as deep as in the smaller specimens and the head is smaller in relation to the body (37.2

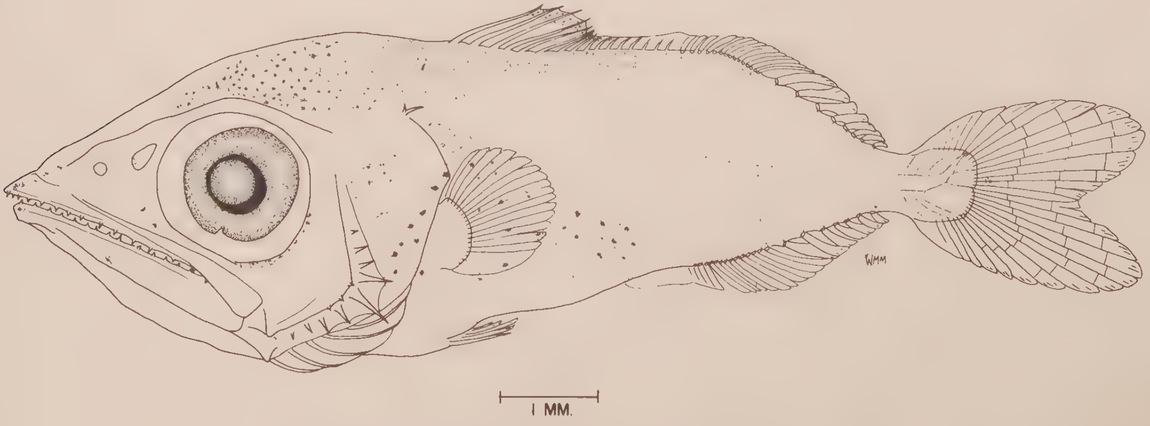

FIGURE 16.—*Katsuwonus pelamis*, 10.9 mm. total length.

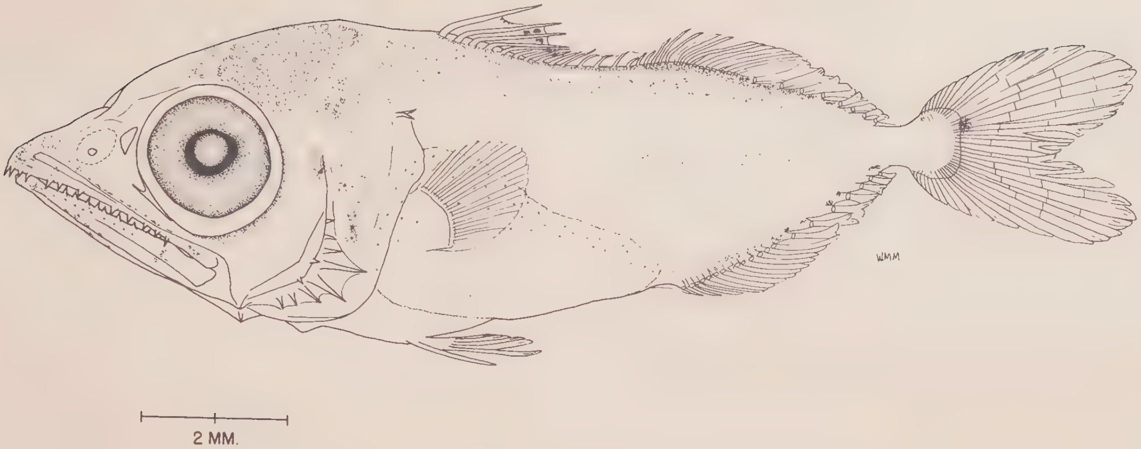

FIGURE 17.—*Katsuwonus pelamis*, 14.5 mm. total length.

percent of total length) than in the previous specimens. The abdominal sac is elongate, and the anal opening is very close to the insertion of the anal fin.

The nostrils are further differentiated, with the round, anterior nostril about one-fifth the size of the triangular, posterior one. The mouth is relatively smaller, 57.9 percent of the head length, and bears about 15 teeth on the upper jaw and about 17 teeth on the lower jaw. Six teeth are also evident on the palatine bone.

The dorsal fin has 16 spines, 15 rays, and 8 finlets, and the first dorsal has assumed the characteristic concave outline of the adult fin. The pelvic fins are very well developed and appear to be a little more posterior than on previous specimens. The pectoral fins have 20 rays, while the well-forked caudal has 22+22 rays.

There are 20 precaudal and 21 caudal vertebrae. The first haemapophysis appears on the 8th or 9th vertebra, while the first completely closed haemal arch is on the 12th. Neither the inferior foramina nor the large haemal arches, which form what Kishinouye (1923) calls the "trellis" and Godsil and Byers (1944) call a "complex basket work," are developed.

Pigmentation is more extensive in all areas described on previous specimens. The chromatophores over the snout have increased in number and line the entire length of the upper jaw. Similarly, two-thirds of the length of the lower jaw is also lined with chromatophores. The midbrain is completely covered with dark, very-closely set chromatophores, and the small patches over the forebrain and on the side of the head immediately posterior to the brain are more intense. The 7 or 8 chromatophores on the surface of the opercle, posterior to the eye, are very large and noticeable. The pigmentation along the posteroventral margin of the orbit is also more intense and extends along nearly half the circumference. Dorsally, the band of chromatophores on the caudal trunk is much wider. It tapers posteriorly and finally terminates near the base of the 5th dorsal finlet. Six or seven darkly pigmented spots are present on the outer edge of the interradial membranes of the first dorsal fin between the 2d and 6th spines. The base of the anal fin is lined with tiny chromatophores, and 3 fairly large chromatophores are present at the bases of the first 3 anal finlets. A band of small chromatophores is also present on the midlateral line beginning at a vertical through the second dorsal insertion and extending to a vertical through the base of the 4th dorsal finlet. The single, large chromatophore at the midventral line of the caudal peduncle still persists, as do the large chromatophores over the dorsal half of the abdominal sac.

A 20.0-mm. specimen, which is not illustrated, was taken at a night-light station in Kingman Reef lagoon, and this individual already shows the characteristic appearance of the juvenile form. The body is narrow and long, with the greatest depth located at a vertical through the pelvic-fin insertion and equal to about one-fourth the total length. The head length is about one-third the total length, and the snout still retains the rather sharply pointed profile. Except for the increase in pigmentation over the body, this specimen resembles the 14.5-mm. one very closely. A stained specimen of a similar size shows the dorsal fins with 16 spines, 15 rays, and 8 finlets, and the anal fin with 15 rays and 7 finlets. The pectoral fins consist of 20 or 21 rays and the caudal fin has 22+22 rays. The vertebrae number 20 precaudals and 21 caudals, with the first haemapophysis on the 9th and the first closed haemal arch on the 11th vertebra. The inferior foramina are just beginning to form on the 13th through the 22d vertebrae, but they are not yet completely closed.

This description agrees very closely with Schaefer and Marr's (1948b) 21-mm. specimen and also with Kishinouye's (1926) 26-mm. specimen. Examination of other stained specimens (22 mm., 27 mm., 33 mm., and 49 mm.) shows that many of the adult complement of meristic characters have appeared by the time the species has reached 27 mm. in length. The inferior foramina are completely closed on the 14th through the 33d and 34th vertebrae in the 27- and 49-mm. specimens, respectively. The foramina are slightly increased in size on the latter specimen, but the trellis is still not evident.

LITTLE TUNNY (*EUTHYNNUS YAITO*)

No specimen of *E. yaito* was recognized in our collections. The following description is based on more than 100 larvae, believed to be *Euthynnus*, which were taken in East Indian waters during the *Dana* Expedition of 1928–30. The largest specimen (12.25 mm.) has 39 vertebrae and seems identical in external appearance to the two *E. lineatus* (21 and 26 mm.) taken by the California Department of Fish and Game from the waters off Costa Rica and also to the juveniles of 20 *E. alletteratus* (25 to 55 mm.) taken by the U. S. Fish and Wildlife Service, Gulf Fisheries Investigations, from the Gulf of Mexico. That the larva is definitely not *E. lineatus* can be seen from the vertebral count, for *E. lineatus* normally has only 37 vertebrae. Positive identification, either as *E. yaito* or *E. alletteratus*, would be relatively easy if the gill rakers were fully developed. Since they are not, the larva was designated as *E. yaito* because this species occurs in the central and western Pacific Ocean, while *E. alletteratus* is found in the Atlantic Ocean and the Mediterranean Sea.

The smallest specimen identified as *E. yaito* measures 4.6 mm. in total length (fig. 18). The head length is moderate (33.9 percent of the total length) and there are 40 myomeres. The abdominal sac is nearly triangular in shape, as in the two previous species.

The mouth, representing 71.9 percent of the head length, is fairly large and contains 12 and 9 teeth on the upper and lower jaws, respectively. The snout is comparable to that of *K. pelamis* of similar size, and the distance from its tip to the anterior edge of the orbit is almost equal to the diameter of the orbit. There are 3 long spines along the posterior edges of the preopercle, the one at the angle being the longest.

Most of the median fins show very little development, there being about 4 or 5 rays in the caudal and only strong striations representing rays in the

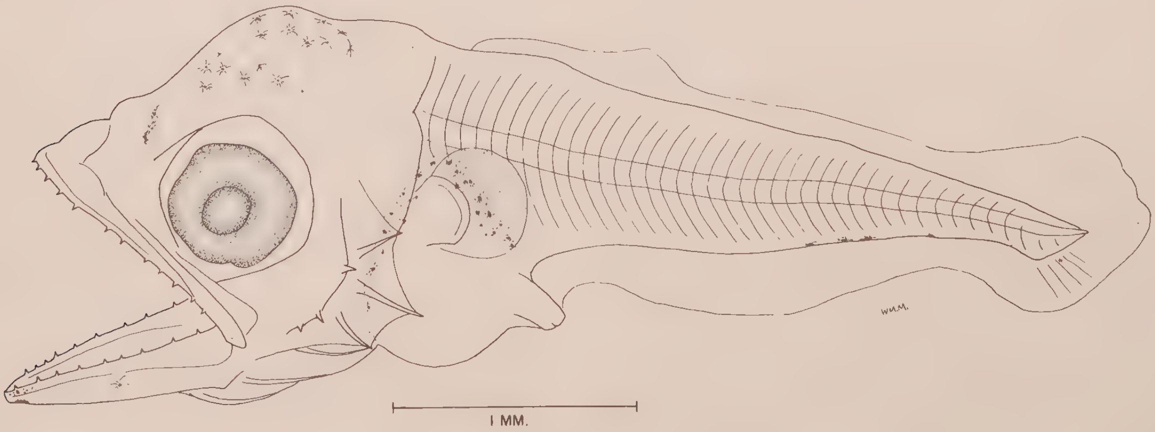

FIGURE 18.—*Euthynnus yaito*, 4.6 mm. total length.

region of the future anal and dorsal fins. The pectoral fins also show only striations, and the pelvic fins are absent.

The pigmentation on the head consists of 3 small chromatophores over the forebrain and about 15 chromatophores over the midbrain. There is a single small chromatophore at the middle of the mandible and another at the symphysis of the pectoral girdle, which is not shown in the drawing. There is no pigmentation along the dorsal edge of the trunk, but 5 chromatophores are present along the ventral margin of the trunk near the caudal region.

A 5.5-mm. specimen (fig. 19) shows marked changes. The proportions of the head, snout, and mouth closely resemble those of *K. pelamis* (see table 4, p. 53). The mouth now contains 13 and 15 teeth in the upper and lower jaws, respectively, and the preopercular spines have increased to 6.

There are 5 short spines in the first dorsal fin and about 9 rays in the caudal. The rest of the median fins and the pectorals still show only strong striations. The pelvic fins are just emerging as small buds.

Pigmentation is more extensive over the midbrain and over the abdominal sac. There is also an increase in the number of chromatophores at the tip of the snout and lower jaw, and the single chromatophore at the middle of the mandible and that at the pectoral symphysis are still evident. In addition, 2 small chromatophores are present on the ventral midline just anterior to the anus, and a single conspicuous chromatophore is present in the first dorsal fin. The dorsal midline of the trunk is still free from pigmentation, while the ventral midline shows 3 well-separated chromatophores in the region of the future anal finlets.

Some noticeable changes are present on the 7.6-mm. specimen (fig. 20), the most prominent

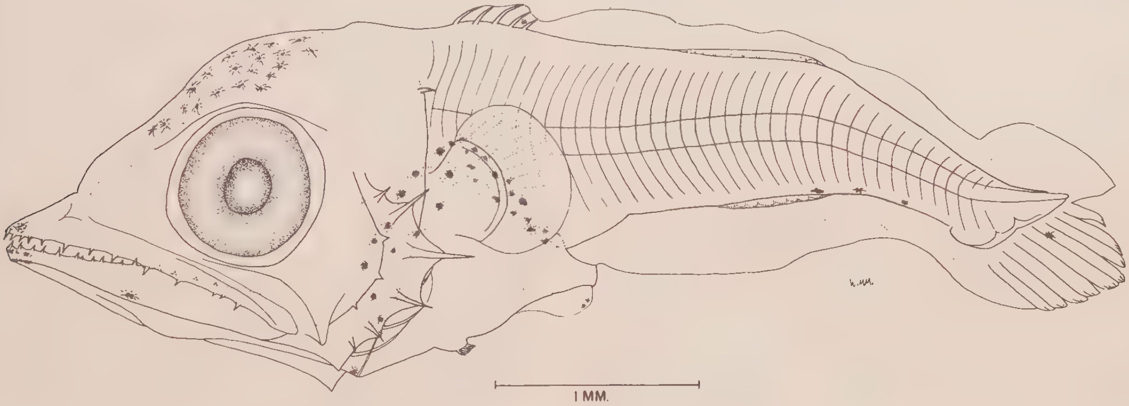

FIGURE 19.—*Euthynnus yaito*, 5.5 mm. total length.

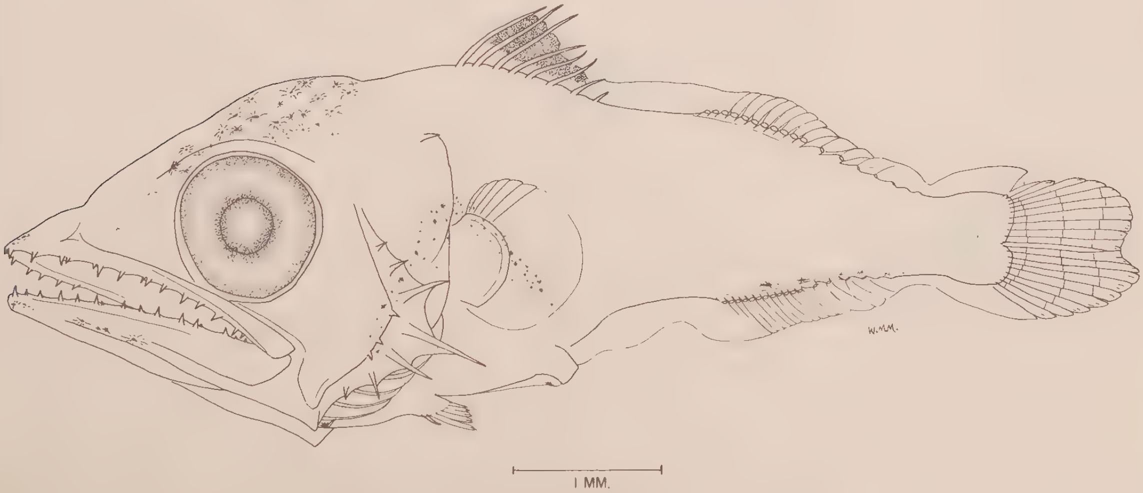

FIGURE 20.—*Euthynnus yaito*, 7.6 mm. total length.

of these being in the pigmentation. The first dorsal fin is almost completely pigmented and the anterior half of the mandible bears a series of 4 or 5 chromatophores.

The head is still large (39.8 percent of the total length) and the length of the snout is much greater than the diameter of the orbit. There are about 16 teeth on both the upper and lower jaws, and 7 spines are noticeable on the posterior edge of the preopercle.

The first dorsal fin has 8 spines, the length of the longest spine being slightly less than half the distance between the dorsal-fin insertions. The second dorsal and anal fin rays are beginning to form and, while the rays themselves are not clearly evident, there appear to be about 11 radials in the second dorsal and 12 in the anal. The radials of the first 7 dorsal finlets and first 6 anal finlets are also evident. The caudal fin shows 9+9 rays, and the pelvic fins, although very small, are complete with 1 spine and 5 rays. Only about 5 rays are noticeable in the pectoral fins. The myomeres remain the same (40 or 41) as in the previous specimen.

A 9.6-mm. specimen (fig. 21) already shows a close resemblance to the juveniles of *E. lineatus* (21 mm.) and *E. alletteratus* (25 mm.), insofar as pigmentation is concerned. The first dorsal fin is heavily pigmented, and the pigmentation at the tip of the snout is more extensive. The number of chromatophores along the lower jaw has increased and chromatophores now extend over two-thirds of the length of the mandible. The chromatophore at the symphysis of the pectoral girdle still persists, and the pigmentation over the rest of the body remains unchanged.

The relative sizes of the head, snout, and mouth are somewhat smaller than those of *K. pelamis* and *N. macropterus*, and only 6 spines are evident along the preopercular edges.

There are 13 spines in the first dorsal fin, the length of the longest spine being greater than half the distance between the dorsal-fin insertions. The second dorsal and anal fins each contains 13 rays. The finlets are poorly developed, but 8 and 7 finlet radials are clearly evident in the dorsal and anal, respectively. The rest of the fins also show an increase in the number of rays.

The largest specimen (not figured) in the series measures 12.25 mm. (tables 4 and 5). Its head is large (40 percent of the total length) and the length of the snout is greater than the diameter of the orbit. The mouth is also large, much more so than in *K. pelamis* and *N. macropterus*, and contains 25 and 28 teeth in the upper and lower jaws, respectively. Staining with alizarin revealed 39 (20+19) vertebrae.

The unpaired fins now have their full complement of spines and rays, with 15 spines in the first dorsal and 14 rays in the second dorsal, and 8 dorsal finlets. The anal fin contains 14 rays and 7 finlets. The longest spine in the first dorsal fin measures about half the distance between the first and second dorsal-fin insertions.

The entire first dorsal fin from the first to the tenth spine is completely pigmented. Small chromatophores are present along the base of the first dorsal fin and over the nape. A series of 4 widely

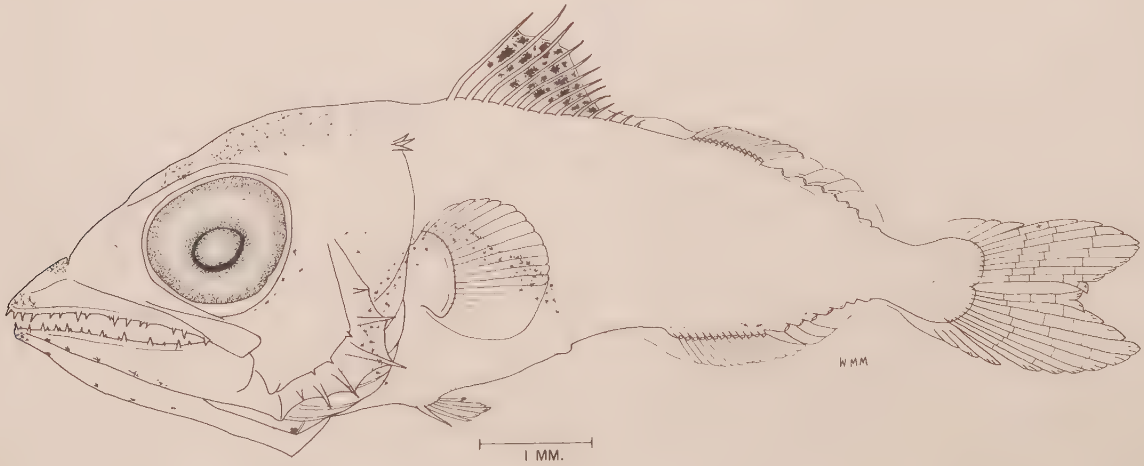

FIGURE 21.—*Euthynnus yaito*, 9.6 mm. total length.

spaced chromatophores is seen along the posterior base of the second dorsal fin and the bases of the first 3 finlets. Similar pigmentation is also present at the bases of the last 3 anal rays and the first 3 finlets. The lower jaw contains 8 well-spaced chromatophores distributed over its entire length, while the rest of the pigmented areas remain as in the 9.6-mm. specimen.

This last specimen has the same pigmentation as the 21-mm. and 26-mm. specimens of *E. lineatus* taken from the waters off Costa Rica by the California Department of Fish and Game. The only major difference is in the number of vertebrae, 37 (20+17), for the 21-mm. Costa Rican specimen as compared with 39 (20+19) for the 12.25-mm. specimen just described.

FRIGATE MACKEREL (*AUXIS THAZARD*)

Of the 38 specimens of *A. thazard* taken by the *Hugh M. Smith* (table 3), only a few specimens were in suitable condition to permit accurate reproduction. Consequently, specimens from the *Dana* collection from the East and West Indies and the Gulf of Panama were used to complete the series.

The 3.7-mm. specimen (fig. 22) described here as probably *A. thazard* is typical of the other specimens in the group ranging from 2.5 to 4.0 mm. in table 3. It has a short head with a very elongate body containing 39 myomeres and tapering very gradually toward the caudal end. The abdominal sac is triangular in shape with the anus located well forward of the middle of the total body length. The greatest depth of the body is at the symphysis of the pectoral girdle, where it is about one-fourth of the total body length.

TABLE 3.—*Number and size range of larval* Auxis thazard *collected by the* Hugh M. Smith *in Hawaiian and equatorial waters*

[See figs. 1 and 2 for location of stations]

Cruise and station	Number of larvae	Size range (mm.)
HAWAIIAN WATERS:		
Cruise 6:		
No. 1A	1	3. 6
No. 7	1	6. 2
No. 8	4	2. 5–8. 2
No. 10	10	2. 7–3. 7
No. 11	2	7. 02, 8. 1
No. 13	12	3. 0–5. 2
Total	30	2. 5–8. 2
EQUATORIAL WATERS:		
Cruise 5:		
No. 21	2	2. 6
No. 51	2	4. 2, 5. 5
Cruise 14:		
No. 26	1	3. 6
No. 29	1	3. 1
Cruise 15: No. 3	1	7. 2
Cruise 18: No. 31	1	4. 0
Total	8	2. 6–7. 2

Since the snout is distorted, no comparisons of the head parts can be made. However, the snout appears very short and blunt and the mouth contains only 5 teeth, 3 on the upper jaw and 2 on the lower. Only 3 preopercular spines are noticeable, the middle one at the angle being the longest. Two small spines are also present on the preopercular surface.

The median fins are represented by a continuous fin membrane which starts at the nape and goes completely around the caudal end to a point slightly anterior to the anal opening. The pectoral fins are also membranous.

The pigmentation is most striking along the ventral midline of the caudal trunk, where 9 small, dark chromatophores are present. While the figured specimen shows a dark chromatophore on the dorsal midline of the caudal peduncle and 2

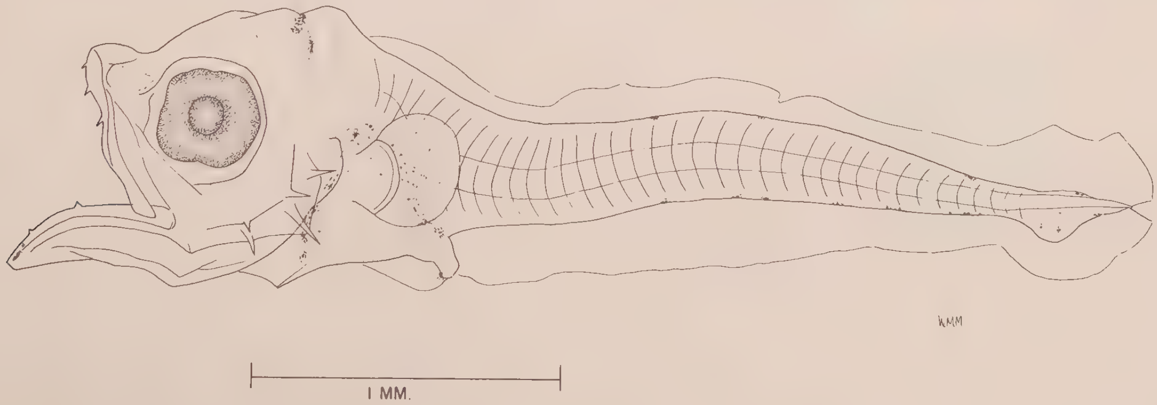

FIGURE 22.—*Auxis thazard* (?), 3.7 mm. total length.

more well-spaced and very light chromatophores near the middle of the body on the dorsal edge, other specimens show only the one on the caudal peduncle. On some specimens even this single chromatophore is absent. Several dark chromatophores are present along the posterior margin of the midbrain, and the very small chromatophores at the tip of the lower jaw are barely noticeable. The abdominal sac is pigmented regularly as in the other species, with most of the pigmentation concentrated along the anterior and dorsal surfaces. A single conspicuous chromatophore is present just anterior to the anal opening, and in this specimen the symphysis of the pectoral girdle does not show any pigmentation.

The smallest specimen identified confidently as *A. thazard* measures 4.5 mm. (fig. 23). The head is moderate (34.2 percent of the total body length) and the body contains 40 myomeres. The snout is short, slightly over three-fourths of the diameter of the orbit, and the mouth is moderately large and measures almost two-thirds of the head length. There are 5 small teeth on the upper jaw and 4 on the lower. The posterior edge of the preopercle bears 3 spines, the longest one located at the angle.

The pigmentation on the head consists of 6 large chromatophores over a small area of the midbrain and a faint tinge of pigment at the tip of the lower jaw. A single chromatophore is present at the symphysis of the pectoral girdle and another just anterior to the anus. The triangular abdominal sac is pigmented regularly, similarly to the three preceding species. A series of 2 to 3 chromatophores is present along the middorsal, midlateral, and midventral lines of the caudal region. In addition, 7 well-spaced chromatophores are present on the posterior half of the trunk along the midventral line.

The unpaired fins are represented by a continuous membrane and except for the caudal fin, where 10 rays are evident, none of the others shows any fin rays. The pectoral fins are also membranous and the pelvic fins are absent.

Only a few changes are noticeable on a 5.5-mm. specimen (fig. 24). The head is small and the moderate mouth, representing 60.3 percent of the head length, contains 12 teeth on each jaw. The snout is somewhat pointed and the distance from its tip to the anterior edge of the orbit is about four-fifths the diameter of the orbit. There are 6 spines along the edge of the preopercle and a small spine is visible in the posttemporal region.

The fins, except for the pelvics, which appear as small buds, show relatively little change from the specimen described above.

The pigmentation on the head consists of about 13 chromatophores which are closely grouped over the midbrain, the rest of the head being unpigmented. The abdominal sac remains the same as in the previous specimen. A series of 2 to 4 chromatophores is present along the middorsal, midlateral, and midventral lines of the caudal region. In addition, 2 widely spaced chromatophores are present along the ventral midline anterior to the caudal peduncle.

Further changes are apparent on a 7.05-mm. specimen (fig. 25). The head is slightly larger and the anus is at the middle of the total length of the body. The snout is pointed and is almost equal in length to the diameter of the orbit. The mouth is large and represents 61.4 percent

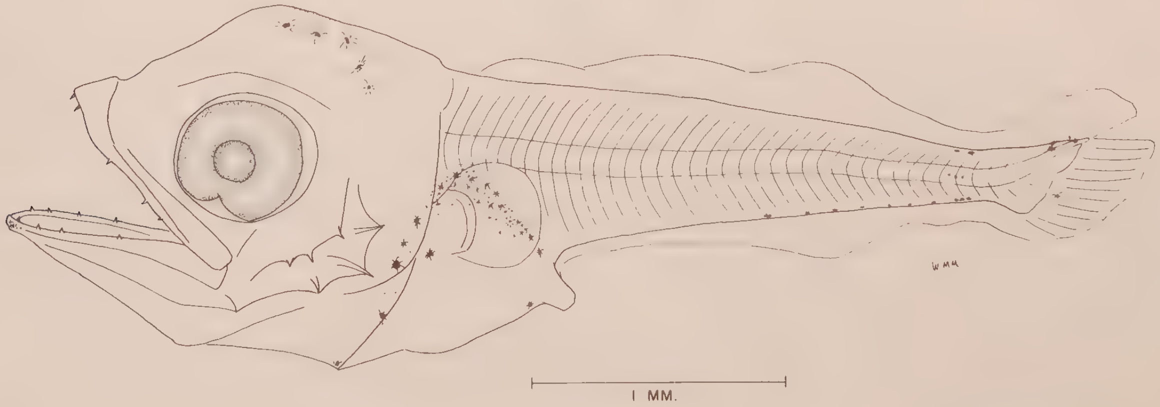

FIGURE 23.—*Auxis thazard*, 4.5 mm. total length.

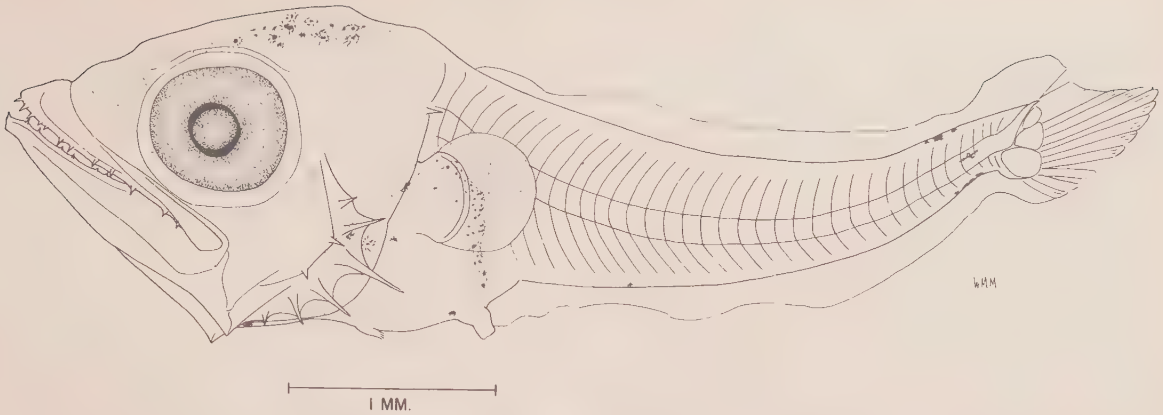

FIGURE 24.—*Auxis thazard,* 5.5 mm. total length.

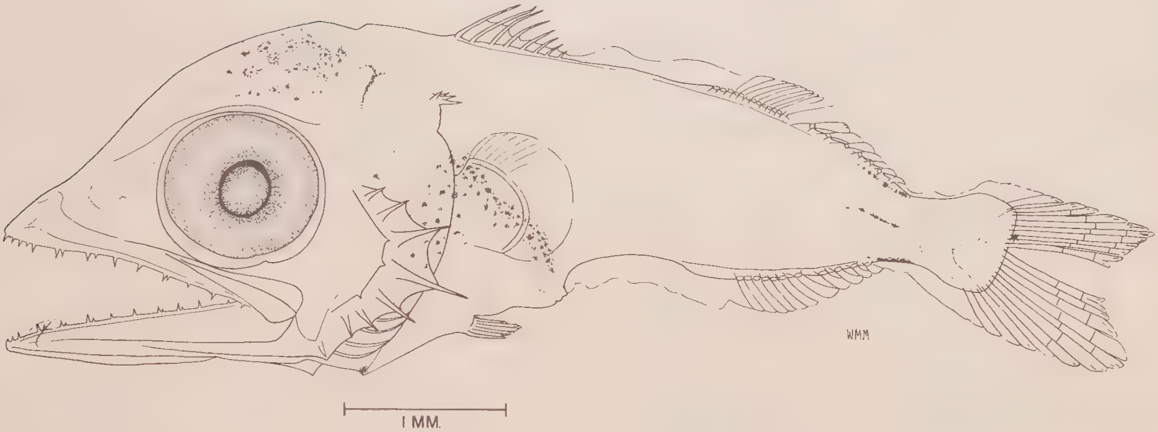

FIGURE 25.—*Auxis thazard,* 7.05 mm. total length.

of the head length. Sixteen to seventeen prominent teeth are present on each ramus of the upper and lower jaws, and 1 tooth is evident on the palatine bone. There are 7 preopercular spines: 2 spines on both the vertical and horizontal edges and 3 long spines at the angle, the middle one being the longest. The single posttemporal spine now has 4 prongs.

The first dorsal fin has 8 spines, the second through the fourth spines being longer than the first. The length of the longest spine is less than one-third the distance between the insertions of the first and second dorsal fins. About 10 rays are present in the second dorsal fin, followed by 6 or 7 dorsal finlets. The anal fin contains about 6 rays and 4 to 5 finlets, while the caudal fin with 10+11 rays is just beginning to fork. The pectoral fins have 7 rays, and the well-developed pelvic fins have 1 spine and 3 to 4 rays.

The pigmentation over the head and the abdominal sac is more extensive than on the previous specimen, and the chromatophores on the caudal region now number 6, 5, and 4 along the mid-dorsal, midlateral, and midventral lines, respectively. The chromatophore at the symphysis of the pectoral girdle is still present, but the single chromatophore anterior to the anal opening is absent. In addition to these, only 1 very faint chromatophore is present on the side of the head near the dorsal origin of the preopercle.

After staining, the 7.05-mm. specimen shows 11 completely ossified vertebrae. From the 12th through the 15th vertebrae only the bases of the neural and haemal arches are ossified. The urostyle is completely ossified, while the 2 preceding vertebrae are only partially so. There are 40 myomeres on this specimen.

Except for a slight increase in pigmentation, an 8.20-mm. specimen (not figured) shows development similar to that of the 7.05-mm. specimen just described. The most noticeable differences are the absence of the chromatophore at the symphysis of the pectoral girdle and the presence of a few small chromatophores on the first dorsal fin.

A 9.7-mm. specimen (fig. 26) has the same general appearance as the preceding specimen. The head (34.7 percent of the total length) appears small, while the anus is now located in the posterior half of the body.

There are 9 spines in the first dorsal fin, the length of the longest one being less than one-fourth the distance between the insertions of the first and second dorsal fins. There are 12 rays in the second dorsal followed by 8 dorsal finlets. The anal consists of 10 rays and 7 finlets. Each pectoral fin contains 15 rays, while the pelvics are complete with 1 spine and 5 rays. The caudal fin consists of 12 dorsal and 13 ventral rays.

Only slight changes are noted in the pigmentation, with 3 chromatophores present over the forebrain, 1 over the tip of the snout, and a few scattered chromatophores over the preopercle. The series of chromatophores along the middorsal line has increased to 16 and extends almost to the insertion of the second dorsal fin. Similarly, the chromatophores along the midventral line also have extended forward to the middle of the anal fin. The midlateral series contains 7 chromatophores.

The 11.2-mm. specimen (fig. 27) differs in several ways from the 9.7-mm. specimen. The head and snout appear much smaller than those of the three previous species. The mouth, however, is moderate (representing 58.6 percent of the head length) and contains 21 and 18 teeth on the upper and lower jaws, respectively. The anus has moved back still further, and the abdominal sac has become more elongate. The nasal depression has completely divided into two separate nostrils, the anterior one being associated with the nasal rosette.

The dorsal and anal fins and finlets have the full complement of spines and rays, and the

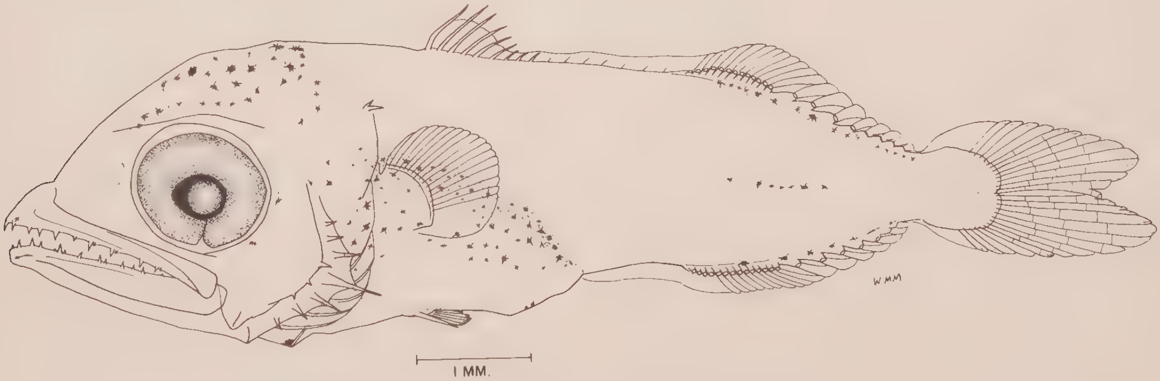

Figure 26.—*Auxis thazard*, 9.7 mm. total length

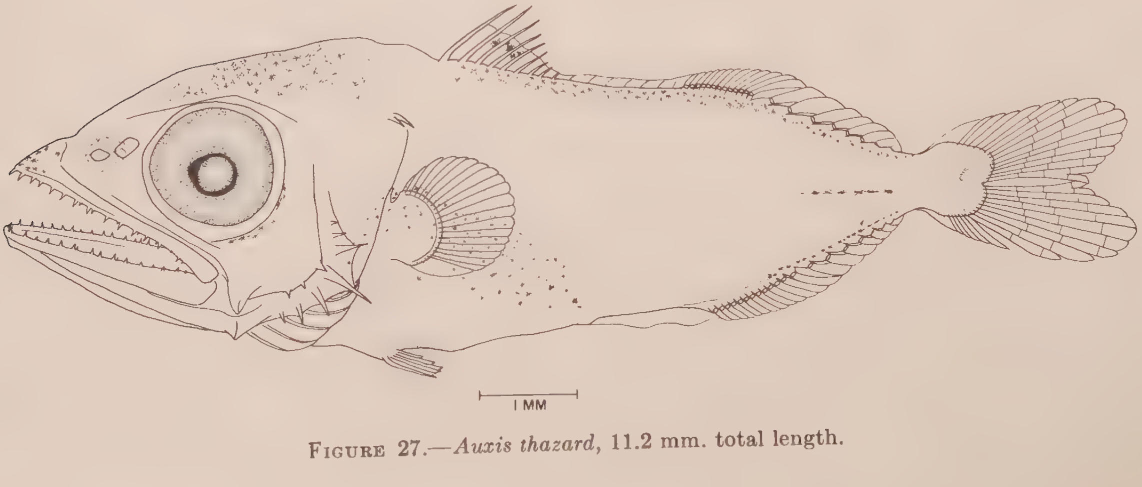

Figure 27.—*Auxis thazard*, 11.2 mm. total length.

length of the longest spine of the first dorsal fin is slightly less than one-third the distance between the first and second dorsal-fin insertions. The pectoral fins have 19 or 20 rays, while the caudal fin consists of 14+14 rays.

There are quite a few changes in the pigmentation at this size. The first dorsal fin contains 3 large chromatophores, and the pigmentation over the dorsal edge of the body now extends to the origin of the first dorsal fin. Other areas showing increased pigmentation are the snout, midbrain, and posteroventral margin of the orbit.

The 11.2-mm. specimen has 7 rather weak spines representing the future subcutaneous spines of the dorsal interspace (Schaefer and Marr, 1948a). The specimens of juvenile *A. thazard* measuring between 11 and 50 mm. from Costa Rica, Colombia, and the Galapagos Islands also have weak spines in the dorsal interspace. In many instances these spines project freely and are easily seen. On the basis of all characters considered, the larvae described here are identical with the juveniles of *A. thazard* from the coastal waters of Central America.

COMPARISON OF SPECIES

It is extremely difficult, if not impossible, to differentiate the larvae of various species of tuna by using the methods employed in identifying the adults. Measurements and meristic counts are not applicable because the larvae are undergoing rapid growth and differentiation. Development is apparently so rapid that even specimens of comparable sizes show marked differences in many characters.

During this study it was found that certain chromatophores and patterns of pigmentation persisted throughout the size ranges examined, and these markings seemed much more reliable than the other characters. Consequently, identification and description of the various species were based primarily on pigmentation, and the other characters were used only supplementally (tables 4 and 5).

Table 4.—*Comparison of body proportions among larvae of four species of tuna, by total length*

[Asterisk (*) indicates measurements not accurate; snout distorted in preservation]

Size group	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Euthynnus yaito*	*Auxis thazard*
Head length/ total length:	*Percent*	*Percent*	*Percent*	*Percent*
3 mm	*31. 2	*28. 3	----	*25. 3
4 mm	----	----	33. 9	34. 2
5 mm	36. 8	38. 7	37. 7	35. 8
6 mm	32. 4	38. 5	41. 7	33. 0
7 mm	35. 2	43. 2	39. 8	39. 4
8 mm	36. 4	41. 3	38. 8	----
9 mm	37. 9	----	33. 5	34. 7
10 mm	----	38. 4	----	36. 2
11 mm	----	----	----	36. 3
12 mm	----	----	40. 0	----
14 mm	39. 7	37. 2	----	----
Mouth length/head length:				
3 mm	*57. 8	*69. 7	----	*59. 4
4 mm	----	----	71. 9	65. 4
5 mm	60. 1	71. 6	72. 0	60. 3
6 mm	57. 0	68. 2	66. 0	63. 1
7 mm	62. 1	68. 6	67. 1	61. 4
8 mm	60. 5	66. 0	61. 3	----
9 mm	61. 9	----	59. 1	56. 9
10 mm	----	67. 9	----	55. 7
11 mm	----	----	----	58. 6
12 mm	----	----	65. 3	----
14 mm	56. 9	57. 9	----	----
Snout length/orbit diameter:				
3 mm	*65. 0	*75. 0	----	*66. 7
4 mm	----	----	99. 9	85. 0
5 mm	68. 9	103. 6	103. 6	81. 5
6 mm	70. 5	98. 2	105. 8	88. 2
7 mm	86. 2	94. 1	117. 4	90. 7
8 mm	82. 7	93. 9	91. 3	----
9 mm	104. 3	----	91. 6	86. 4
10 mm	----	103. 4	----	78. 6
11 mm	----	----	----	88. 4
12 mm	----	----	112. 9	----
14 mm	100. 6	87. 5	----	----
Total length of specimen:	*Mm.*	*Mm.*	*Mm.*	*Mm.*
3 mm	*3. 90	*3. 70	----	*3. 70
4 mm	----	----	4. 60	4. 50
5 mm	5. 50	5. 35	5. 50	5. 50
6 mm	6. 40	6. 70	6. 00	6. 25
7 mm	7. 15	7. 10	7. 60	7. 05
8 mm	7. 95	8. 75	8. 00	----
9 mm	9. 20	----	9. 60	9. 70
10 mm	----	10. 90	----	10. 90
11 mm	----	----	----	11. 20
12 mm	----	----	12. 25	----
14 mm	14. 25	14. 50	----	----

Among the four species described, *E. yaito* and *A. thazard* can be separated from *N. macropterus* and *K. pelamis* quite readily by the pigmentation of the body. Larvae of both species bear a single chromatophore at the symphysis of the pectoral girdle and another on the midline of the body just anterior to the anal opening. The occurrence of these chromatophores is somewhat variable, and in some instances either one of the two may be absent. Nevertheless, the presence of either one is quite conclusive evidence that the specimen is either *E. yaito* or *A. thazard*, since no other species examined has these chromatophores. Mead (1951), in his descriptions of *A. thazard* and *E. lineatus* from the Pacific coast of Central America, found that the chromatophore at the symphysis of the pectoral girdle was present in the majority of his specimens. Wade (1951) did not mention this chromatophore, but our examination of the larvae collected by him from Philippine waters showed it to be regularly present on specimens which he designated as *E. yaito* and *Auxis* sp.(?), and absent from *K. pelamis* and *N. macropterus*. Besides this character, *E. yaito* and *A. thazard* bear a series of chromatophores (3 or more) along the ventral midline of the caudal trunk.

Three, or possibly four, distinctive patterns of pigmentation permit the separation of *E. yaito* from *A. thazard*. The first dorsal fin is generally more heavily pigmented in *E. yaito*. The first sign of this pigmentation is seen on a 5.5-mm. specimen with the appearance of 1 faint chromatophore. When the species is about 7 mm. in length the distal half of the first dorsal fin appears black. The pigmented area increases with growth of the larva and the entire fin is almost completely pigmented at about 12 mm. In *A. thazard* this pigmentation does not start to appear until the species has attained a length of about 10 mm. An 11.2-mm. specimen has only 2 or 3 faint chromatophores near the distal edge of the fin membrane.

TABLE 5.—*Summary of the more prominent diagnostic characters of tuna larvae at various sizes, by species*

Character	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Euthynnus yaito*	*Auxis thazard*
	3.9 mm.	**3.7 mm.**	**4.6 mm.**[1]	**4.5 mm.**[1]
Teeth	Not clearly seen	4 upper; 6 lower	12 upper; 9 lower	5 upper; 4 lower.
Preopercular spines	3	3	3	3.
Myomeres	About 40	Incomplete	40	40.
1st dorsal spines				
1st dorsal fin outline				
Pigmentation:				
1st dorsal fin				
Middorsal line	No chromatophores	No chromatophores	No chromatophores	2 chromatophores on caudal peduncle.
Midlateral line	do	do	do	3 chromatophores on caudal peduncle.
Midventral line	do	1 chromatophore on caudal peduncle.	5 chromatophores on posterior half of body.	3 chromatophores on caudal peduncle; 7 to middle of body.
Tip of pectoral girdle	do	No chromatophores	1 chromatophore	1 chromatophore.
Anal opening	do	do	No chromatophores	Do.
Midbrain	4 chromatophores over small area.	10 chromatophores over large area.	15 chromatophores over large area.	6 chromatophores over small area.
Forebrain	No chromatophores	No chromatophores	3 chromatophores	No chromatophores.
Mandible (other than at tip)	do	do	1 chromatophore at middle	Do.
	5.5 mm.	**5.35 mm.**	**5.5 mm.**[1]	**5.5 mm.**
Teeth	8 upper; 4 lower	13 upper; 11 lower	13 upper; 15 lower	12 each jaw.
Preopercular spines	6	6	6	6.
Myomeres	38	41 or 42	40 or 41	About 39.
1st dorsal spines			5; longest spine <⅓ dorsal interspace.[2]	
1st dorsal fin outline				
Pigmentation:				
1st dorsal fin			1 chromatophore	
Middorsal line	No chromatophores	No chromatophores	No chromatophores	3 chromatophores on caudal peduncle.
Midlateral line	do	do	do	2–3 chromatophores on caudal peduncle.
Midventral line	do	1 chromatophore on caudal peduncle.	3 chromatophores at bases anal and finlets.	4 chromatophores on caudal peduncle; 2 near middle of body.
Tip of pectoral girdle	do	No chromatophores	1 chromatophore	1 chromatophore.
Anal opening	do	do	2 chromatophores	Do.
Midbrain	14 chromatophores over small area.	24 chromatophores over large area.	18 chromatophores over wide area.	13 chromatophores over moderate area.
Forebrain	No chromatophores	No chromatophores	3 chromatophores	No chromatophores.
Mandible (other than at tip)	do	do	1 chromatophore at middle	Do.
	7.15 mm.	**7.1 mm.**	**7.6 mm.**[1]	**7.05 mm.**
Teeth	10–11 upper; 6–7 lower	15 each jaw	16 each jaw	16–17 each jaw.
Preopercular spines	6	7	7	7.
Myomeres	40	41	40 or 41	40.
1st dorsal spines	7; longest spine <½ dorsal interspace.[2]	8; longest spine <⅓ dorsal interspace.[2]	8; longest spine <½ dorsal interspace.[2]	8; longest spine <⅓ dorsal interspace.[2]
1st dorsal fin outline				
Pigmentation:				
1st dorsal fin	6 chromatophores	1 chromatophore	Almost completely pigmented.	No chromatophores.
Middorsal line	No chromatophores	No chromatophores	No chromatophores	6 chromatophores on caudal peduncle.
Midlateral line	do	do	do	5 chromatophores on caudal peduncle.
Midventral line	do	1 chromatophore on caudal peduncle.	2 chromatophores—well separated.	4 chromatophores on caudal peduncle.
Tip of pectoral girdle	do	No chromatophores	1 chromatophore	1 chromatophore.
Anal opening	do	do	do	No chromatophores.
Midbrain	50+ chromatophores over small area.	50 chromatophores over large area.	45 chromatophores over entire area.	25 chromatophores over moderate area.
Forebrain	No chromatophores	2 chromatophores	3 chromatophores	No chromatophores.
Mandible (other than at tip)	do	1 chromatophore ¼ distance from tip.	4–5 chromatophores over anterior half.	Do.

See footnotes at end of table.

TABLE 5.—*Summary of the more prominent diagnostic characters of tuna larvae at various sizes, by species*—Continued

Character	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Euthynnus yaito*	*Auxis thazard*
	7.95 mm.	**8.75 mm.**	**8.0 mm.**[1]	**7.7 mm.**[1]
Teeth	9–10 each jaw	16–18 each jaw	18 upper; 19 lower	15 upper; 17 lower.
Preopercular spines	7	7	7	7.
Myomeres	40	41–42	40	40–41.
1st dorsal spines	7	8 or 9	10; longest spine=⅔ dorsal interspace.[2]	6; longest spine=¼ dorsal interspace.[2]
1st dorsal fin outline				
Pigmentation:				
1st dorsal fin	Almost entire height to 6th spine.	6 chromatophores on outer fin edge.	Large chromatophores on outer ⅔ of fin.	No chromatophores.
Middorsal line	No chromatophores	6–8 chromatophores at base 1st dorsal; 1 at origin 2d dorsal.	No chromatophores	8 chromatophores on caudal peduncle.
Midlateral line	do	No chromatophores	do	4 chromatophores on caudal peduncle.
Midventral line	do	3 chromatophores at base anal; 1 on caudal peduncle.	2 chromatophores at bases anal and finlet.	6 chromatophores at bases anal and finlet.
Tip of pectoral girdle	do	No chromatophores	1 chromatophore	1 chromatophore.
Anal opening	do	do	No chromatophores	Do.
Midbrain	22 chromatophores over small area.	45 + chromatophores over wide area.	About 46 chromatophores over entire area.	About 25 chromatophores over fairly large area.
Forebrain	No chromatophores	2–3 chromatophores	5–6 chromatophores	No chromatophores.
Mandible (other than at tip)	do	1 chromatophore ½ distance from tip.	5 chromatophores over anterior half.	Do.
	9.2 mm.	**10.9 mm.**	**9.6 mm.**[1]	**9.7 mm.**[1]
Teeth	12 each jaw	15 each jaw	17 upper; 19 lower	13 upper; 14 lower.
Preopercular spines	7	9	6	7.
Myomeres/vertebrae	13 ossified vertebrae (on 10.2-mm. specimen).	20+21 vertebrae (on 9.85-mm. specimen).	20+19 vertebrae (on 9.7-mm. stained specimen).	40 myomeres.
1st dorsal spines	10; longest spine=¾ dorsal interspace.[2]	13; longest spine <½ dorsal interspace.[2]	13; longest spine >½ dorsal interspace.[2]	9; longest spine <¼ dorsal interspace.[2]
1st dorsal fin outline	Slightly convex	Concave	Slightly concave	Convex(?).
Pigmentation:				
1st dorsal fin	Almost entire height to 8th spine.	Chromatophores on outer edge to 12th spine.	Distal ⅔ nearly completely black.	No chromatophores.
Middorsal line	No chromatophores	Chromatophores to 1st dorsal finlet.	No chromatophores	5 chromatophores on caudal peduncle; 11 chromatophores at bases 2d dorsal and finlets.
Midlateral line	do	6 chromatophores forward of caudal peduncle.	do	7 chromatophores on caudal peduncle.
Midventral line	do	4 chromatophores at bases anal and finlets; 1 on caudal peduncle.	2 chromatophores at bases anal and finlet.	3 chromatophores on caudal peduncle; 6 chromatophores at bases anal and finlets.
Tip of pectoral girdle	do	No chromatophores	1 chromatophore	1 chromatophore.
Anal opening	do	do	No chromatophores	2 chromatophores.
Midbrain	Chromatophores (number?) over small area.	80 chromatophores over large area.	23 chromatophores over large area.	About 25 chromatophores over large area.
Forebrain	No chromatophores	4 chromatophores	5 chromatophores	3 chromatophores.
Mandible (other than at tip)	do	1 chromatophore	4 chromatophores over anterior two-thirds.	No chromatophores.
	14.25 mm.	**14.5 mm.**	**12.25 mm.**[1]	**11.2 mm.**[1]
Teeth	13–14 each jaw	15 upper; 17 lower	25 upper; 28 lower	21 upper; 18 lower.
Preopercular spines	6	8	8	7.
Vertebrae	18+20 (on 12-mm. specimen)	20+21	20+19	Not observed.
1st dorsal spines	14; longest spine=⅗ dorsal interspace.[2]	16; longest spine=½ dorsal interspace.[2]	15; longest spine about ½ dorsal interspace.[2]	9; longest spine <⅓ dorsal interspace.[2]
1st dorsal fin outline	Convex	Concave	Concave	Convex(?).
Pigmentation:				
1st dorsal fin	Completely black	6 or 7 chromatophores on outer edge of fin.	First 10 spines black	3 chromatophores near distal edge.
Middorsal line	Band of chromatophores to 1st finlet.	Band of chromatophores to 5th finlet.	4 chromatophores at bases 2d dorsal and finlets.	Series of chromatophores from 1st dorsal origin to caudal peduncle.
Midlateral line	No chromatophores	Band of chromatophores from 2d dorsal to 4th finlet.	No chromatophores	7 chromatophores on caudal peduncle.
Midventral line	do	Band of chromatophores at bases anal and finlets; 1 on caudal peduncle.	4 chromatophores at bases anal and finlets.	Series of chromatophores from anal insertion to caudal peduncle.
Tip of pectoral girdle	do	No chromatophores	1 chromatophore	1 chromatophore.
Anal opening	do	do	No chromatophores	No chromatophores.
Midbrain	Numerous chromatophores over small area.	Numerous chromatophores over large area.	Numerous chromatophores over large area.	About 36 chromatophores over medium-sized area.
Forebrain	No chromatophores	12 chromatophores	5 chromatophores	4 chromatophores.
Mandible (other than at tip)	do	Chromatophores on ⅔ of length.	8 chromatophores over entire length.	No chromatophores.

[1] *Dana* Expedition collection.

[2] Distance between insertions of first and second dorsal fins.

The second character that separates these two species is the series of chromatophores along the mandible in *E. yaito*. The first indication of mandibular pigmentation is seen in the 4.6-mm. specimen, where a single chromatophore appears at the middle of the lower jaw. *A. thazard* lacks this pigmentation until it reaches a length of about 15 mm. The only other species which has pigment on the mandible is *K. pelamis*, but in our specimens this species showed only 1 chromatophore at about 7 mm., and this persisted unchanged until a length of 10.9 mm. had been reached. At 14.5 mm. the mandible of *K. pelamis* is well pigmented, but at this size other characters easily separated it from *E. yaito*.

Two other areas of pigmentation in *A. thazard* help to separate it from *E. yaito*. These are the dorsal and lateral edges of the body in the caudal region. The chromatophores on the middorsal line are always present in *A. thazard*, while those on the midlateral line appear indistinct among the specimens below 4.5 mm.

It should be mentioned that in *A. thazard* pigmentation of the caudal region varies considerably, especially on the midlateral line. A number of specimens measuring up to 7 or 8 mm. lacked this pigmentation (fig. 28). Whether they represent another species, *A. tapeinosoma*, is difficult to determine, since a complete series of larvae of this type could not be assembled. All other characters of these specimens lead us to believe that they belong to the genus *Auxis*.

Several excellent characters separate *N. macropterus* from *K. pelamis*. Between 8.0 and 14.25 mm., *N. macropterus* can be distinguished from *K. pelamis* by the almost completely pigmented first dorsal fin. This pigmentation is first noticeable on a 6.4-mm. specimen and is represented by a single, small chromatophore. *K. pelamis* also has some pigmentation on the first dorsal fin, which seems to develop much later than in *N. macropterus*, for only 1 or 2 very faint chromatophores are present in specimens measuring about 7 mm.

Another notable character of *N. macropterus* is the complete lack of pigmentation in the caudal region of the body until the larva approaches 14.0 mm. In the remaining three species described here, some pigmentation is present in the caudal region at all sizes.

The final character which is peculiar to *N. macropterus* is the complete absence of pigmentation over the forebrain on specimens of all sizes. In *K. pelamis* this pigmentation is present in specimens down to 7.1 mm. *N. macropterus* smaller than 7.15 mm. can be separated from *K. pelamis* by the small area of pigmentation over half or less than half the area of the midbrain, whereas in *K. pelamis* this pigmentation extends over almost the entire midbrain area. The only possible confusion in separating individuals of these two species measuring less than 7.15 mm. is in the rare cases where the chromatophore at the caudal peduncle of *K. pelamis* is absent. However, in such cases the relatively shorter snout and smaller mouth of *N. macropterus* (table 4), together with the difference in pigmentation over the midbrain, help to separate these two species.

Among *N. macropterus* larger than 9.2 mm., the outline of the first dorsal fin is definitely convex, and the longest spine of the fin is about three-fifths the distance between the first and second dorsal fin insertions (table 5). The fin outline of *K. pelamis* is concave in a 10.9-mm. specimen, and its longest spine is less than one-half the distance between the insertions of the first and second dorsal fins.

Larger specimens of *K. pelamis* can be most readily identified by staining the vertebrae. A count of 20 precaudal and 21 caudal vertebrae is

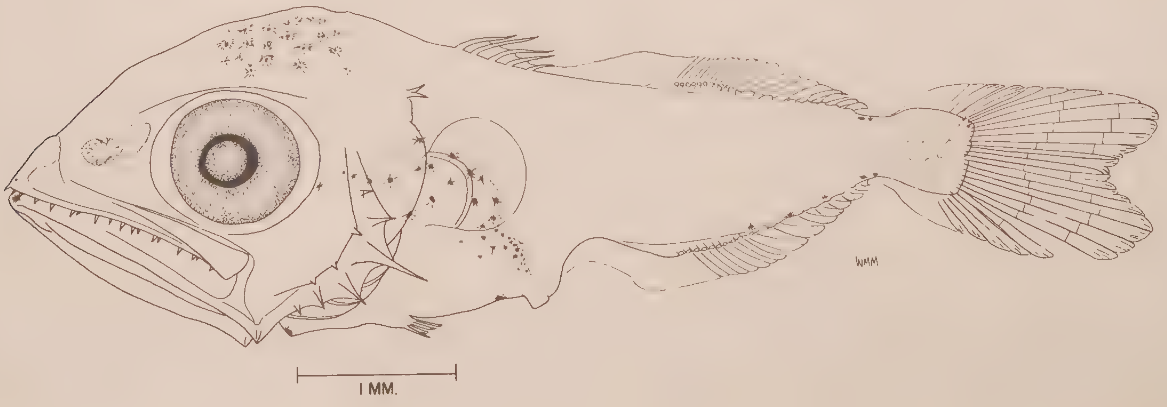

FIGURE 28.—*Auxis* sp. (?), 7.2 mm. total length.

definitive for this species, and this count can be obtained from specimens measuring only 9.85 mm. Where staining is not feasible, this species can be identified by the single distinct chromatophore at the ventral midline of the caudal peduncle throughout the entire size range. This chromatophore is absent only rarely, but at times there may be 2 instead of the usual 1. Moreover, *K. pelamis* between the sizes of 7.1 mm. and 10.9 mm. have a single chromatophore near the tip of the mandible in the smaller specimens and near the middle of the mandible in larger specimens.

K. pelamis smaller than 7.0 mm. can be distinguished from the other species by the single chromatophore at the midventral line of the caudal peduncle, by the larger mouth and longer snout, and by the large area of pigmentation over the midbrain. Forty-one or 42 myomeres can be counted on specimens of *K. pelamis* whereas other species have 41 or fewer.

DISTRIBUTION OF TUNA LARVAE IN THE CENTRAL PACIFIC

In the sections to follow we shall discuss mainly the distribution of the two species of tuna, *Neothunnus macropterus* and *Katsuwonus pelamis*, which comprise the bulk of our catch of tuna larvae, for the purpose of gaining some insight into the distribution and spawning habits of these fish. Included are discussions on horizontal and vertical distribution, species composition of the catches, and spawning areas and seasons as evidenced from the size composition of the catches. In addition to the identified larvae there is a small, unidentified group consisting in the main of small (less than 3 mm.) and damaged larvae. Since there is little reason to suppose this group contains additional species, this and the small group of *Auxis thazard* are not considered in the discussions on distribution and spawning seasons.

A vast area of the Pacific was sampled, extending from 25° N. to 15° S. latitude and from 120° W. to 180° longitude. The hydrography of this area was studied, and experimental fishing with longline gear (described in Niska 1953) also was conducted in the region between 14° N. and 9° S. latitude during the period when the plankton hauls were made.

Hydrographic observations in this region indicate a current system composed of a westerly flowing North Equatorial Current with its southern boundary varying with longitude and with season, but generally at about 10½° N. latitude; a westerly flowing South Equatorial Current with its northern edge at about 5½° N. latitude; and an easterly flowing Equatorial Countercurrent between the North and South Equatorial Currents. The width of the Countercurrent varies from 4° to 7½° and it shifts north and south over a distance of from 2° to 5° during different periods of time and at different longitudes (Cromwell 1954, table 1). These currents could have an important effect on the distribution of free-floating eggs and of newly hatched larvae, which are not yet capable of swimming about extensively.

HORIZONTAL DISTRIBUTION

Range of distribution

Approximate collecting locales for tuna larvae taken during 1950–52 are shown in figure 29. Each dot represents the occurrence of the designated species and has no quantitative connotation. Tuna larvae, both *N. macropterus* and *K. pelamis*, were taken as far north as 25° N. latitude in the vicinity of Midway Island, the most northerly area sampled during this period. Zooplankton collections presently being made in central Pacific waters up to about 45° N. latitude may show a further extension of the northern limit of larval-tuna distribution, for preliminary examination of zooplankton samples collected from this area (at 31° N. latitude along 143° W. longitude) during the winter of 1954 shows a few tuna larvae, too small for positive identification. South of the Equator, larvae have been taken at 14½° S. latitude in the vicinity of Samoa, the southernmost latitude at which a plankton station has been occupied by POFI vessels. In an east-west direction, larvae were taken at all longitudes sampled, from 120° W. to 180°. The area of larval occurrence as shown by the broken lines in figure 29 approaches 4 million square miles.

Latitudinal distribution of *Katsuwonus pelamis* and *Neothunnus macropterus*

The latitudinal distributions of the two species of tuna which comprise almost the entire larval-tuna catch in equatorial waters are plotted in figure 30, together with the corresponding adult catches on longline gear (the latter from Murphy and Shomura 1953a, 1953b). The north-south

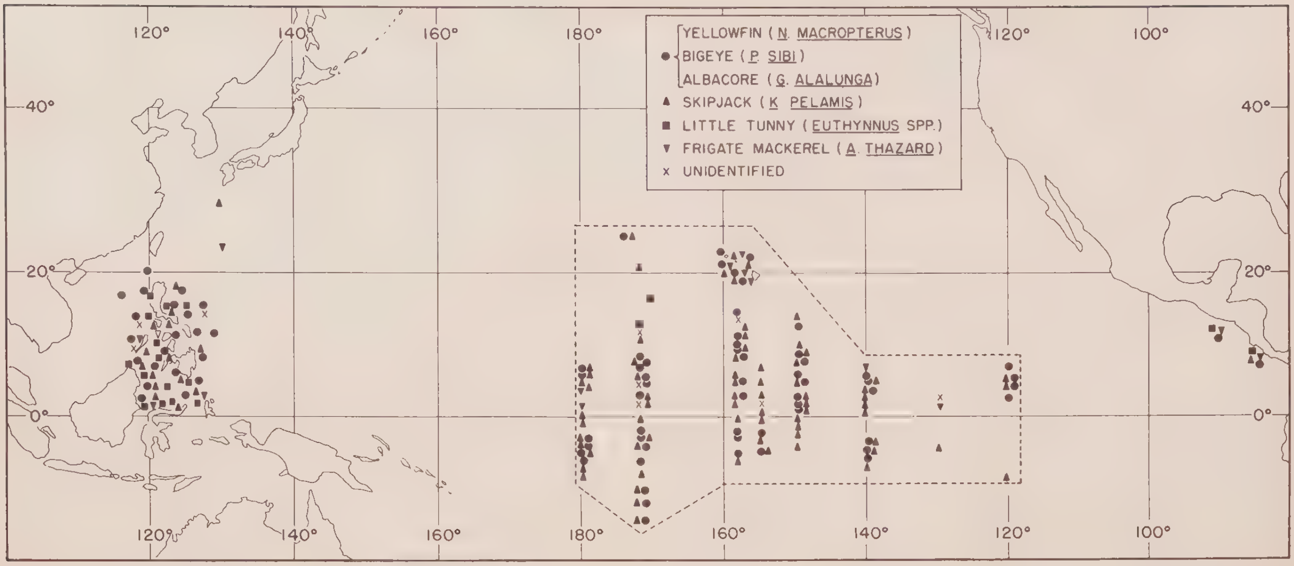

FIGURE 29.—Localities of capture of tuna larvae in the equatorial Pacific. Broken lines enclose area of POFI collections.

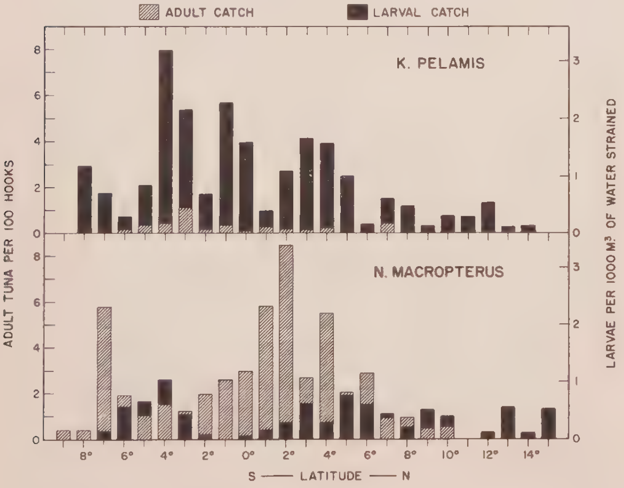

FIGURE 30.—Latitudinal distribution of the adult *Katsuwonus pelamis* and *Neothunnus macropterus*, as indicated by longline catch, and of the larvae.

range was limited by 14° N. and 9° S. latitudes in conformity with the range of fishing stations. The catch figures for both adults and larvae represent the averages of all the longitudes sampled during identical years.

Although our longline catches may not provide a true measure of the abundance of adult *K. pelamis*, they would seem to indicate that the distribution of these fish (fig. 30, upper panel) is somewhat skewed to the south, with the peak at 3° S. latitude. Larval abundance shows a similar trend, but the latitudinal range of the larvae exceeds that of the adults. This is understandable when we realize that fishing effort was reduced at the northern and southern extremities.

The adult *N. macropterus* catches (fig. 30, lower panel) present a different distribution pattern. There are two peaks, one is slightly north of the Equator and another at 7° south of the Equator. As explained by Murphy and Shomura (1953a, 1953b, and 1955) the tunas, especially *N. macropterus*, are perhaps indirectly associated with the phenomenon of upwelling that occurs along the Equator. Large catches of adult *N. macropterus* were made slightly to the north and south of the Equator where the upwelled water had aged sufficiently to allow populations of tuna forage to develop. The larval *N. macropterus* catches show a similar, but more pronounced, bimodal distribution which, although it is slightly displaced to the north, is likely related to the adult catches.

Longitudinal distribution of *Katsuwonus pelamis* and *Neothunnus macropterus*

Consideration of the larval-tuna catches (fig. 31) was limited to stations between 9° N. and 9° S. latitude, the zone in which there was the most concentrated fishing for adults, in order to compare the catches of larval and adult tuna.

It can be seen from the upper panel in figure 31 that the abundance of *K. pelamis* larvae seemed fairly uniform from 180° to 140° W. longitude and the adult abundance was uniform from 170° W.

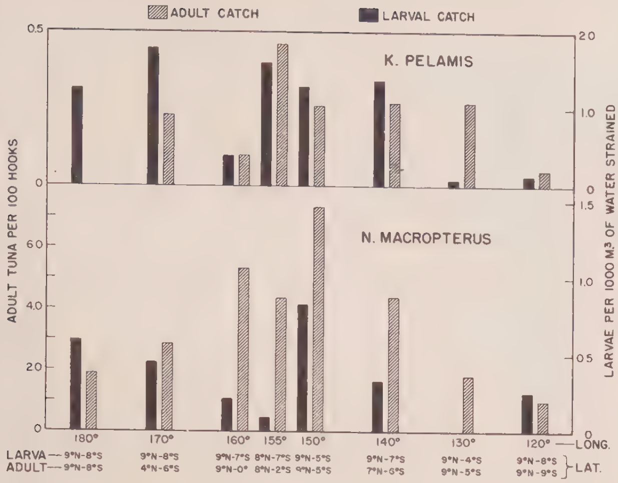

Figure 31.—Longitudinal distribution of the adult *Katsuwonus pelamis* and *Neothunnus macropterus*, as indicated by longline catch, and of the larvae for the area 9° N. to 9° S. latitude.

to 130° W. longitude, apart from the low catches of both larvae and adults at 160° W. longitude. The low catches of larvae at 130° W. and 120° W. longitude suggest that there is little spawning of *K. pelamis* in this region.

The adult *N. macropterus* distribution varied slightly from that of *K. pelamis* (fig. 31, lower panel), for they were found from 180° to 120° W. longitude with a peak at 150° W. longitude. The larval *N. macropterus* abundance also peaked at the 150th meridian, but aside from this there was little correspondence in the density of larvae and adults. The apparent absence of larvae at 130° W. longitude suggests that this longitude may be near the eastern limit of favorable *N. macropterus* spawning grounds. The salient feature of both *N. macropterus* and *K. pelamis* distribution is that, with the exception of *N. macropterus* along 130° W. longitude, tuna larvae were taken at all the longitudes where the adults were found.

West of 180° longitude the adults of *N. macropterus*, *K. pelamis*, and other tunas are caught all the way to the Asian coast. On the basis of the adult-larva relationship, it can be expected that tuna larvae will also be found in the region between 180° and the coast of Asia. This is not entirely supposition, for Wade (1950, 1951) has reported the capture of large numbers of these larvae from the waters surrounding the Philippine Islands. In the eastern Pacific, Schaefer and Marr (1948a, 1948b) and Mead (1951) found larval and juvenile tunas off the Pacific coast of Central America. The widely distributed records of larvae (fig. 29) together with the apparent parallels between adult and larval-tuna catch rates suggest that tuna larvae are generally distributed across the Pacific Ocean, although not necessarily with uniform abundance.

Records of larval-tuna captures in the Atlantic Ocean also seem to support the probability of a transoceanic distribution of tuna larvae. The Equatorial Current system roughly follows the same pattern in the Atlantic Ocean as in the Pacific Ocean, and tuna larvae have been taken (Ehrenbaum 1924) in a band of water between 32° N. and 7° S. latitude from the Cape Verde Islands to the coasts of Florida and Brazil (fig. 32).

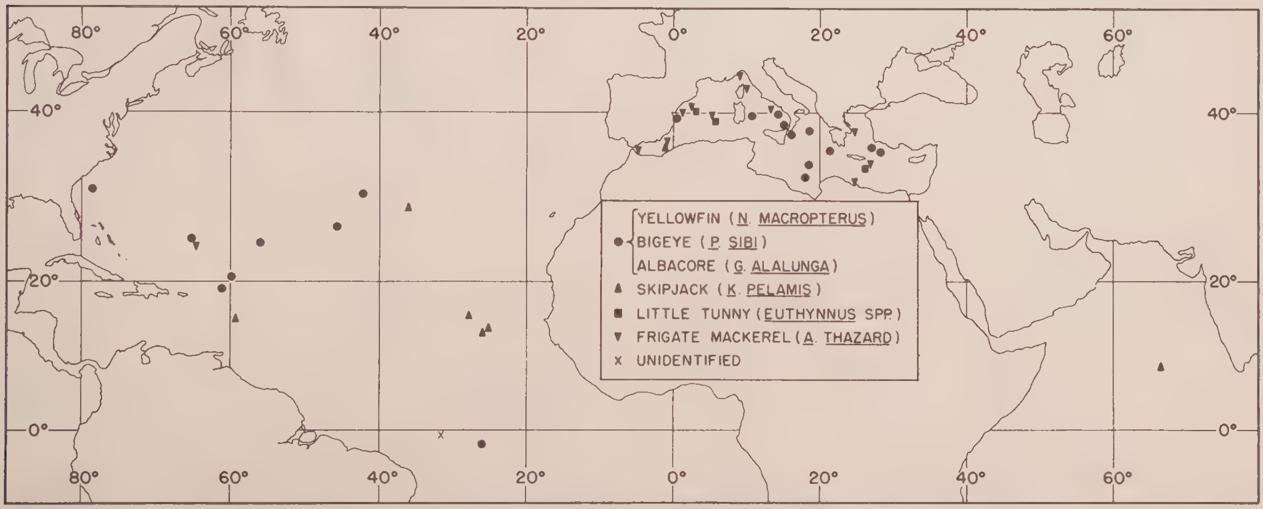

Figure 32.—Localities of capture of larval tunas in the Atlantic and Indian Oceans and in the Mediterranean Sea.

It is interesting to note that there are extensive records of larval tunas in the Mediterranean Sea and a record from the Indian Ocean.

VERTICAL DISTRIBUTION OF TUNA LARVAE

The data from cruise 6 of the *Hugh M. Smith* in Hawaiian waters (fig. 1) were used in studying the vertical distribution of tuna larvae. During each haul, 3 nonclosing nets, fishing at different depths, were towed simultaneously in a horizontal plane for 1 hour. At each station one of the following sets of towing depths was used: 0, 50, 150 meters; 0, 100, 150 meters; 0, 100, 200 meters; or 0, 150, 300 meters (appendix table 2, p. 68). The catches made on this cruise (table 6) show very clearly that tuna larvae are concentrated in the surface layers. Further, it is possible that all or most of the deep catches are contaminants, obtained while the nets were being raised and lowered.

Table 6.—*Abundance of tuna larvae in Hawaiian waters, per 1,000 cubic meters of water strained, for various depths and times of hauling*

[The figures in parentheses represent number of tows]

Time of tow	Depth in meters					
	Surface	50	100	150	200	300
Day	1.70(16)	0.42(4)	0.21(10)	0.08(8)	0.44(8)	0.36(2)
Night	8.49(9)	0.98(2)	0.55(4)	0.71(6)	1.18(3)	1.15(3)

The amount of contamination can be computed if the average concentration of larvae in the upper strata and the time spent by the net in passing through them are known.[2] It is interesting to note that, assuming the surface tows are representative of the upper 50 meters or the layer between the surface and the next shallowest net, contamination correction accounts for all of the deeper night catches and nearly all of the deeper day catches (fig. 33).

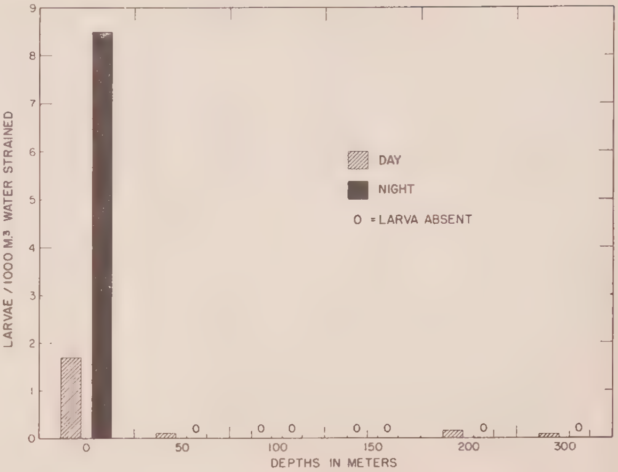

Figure 33.—Vertical distribution of tuna larvae from the Hawaiian area corrected for contamination, assuming that the surface hauls are representative of the upper 50 meters.

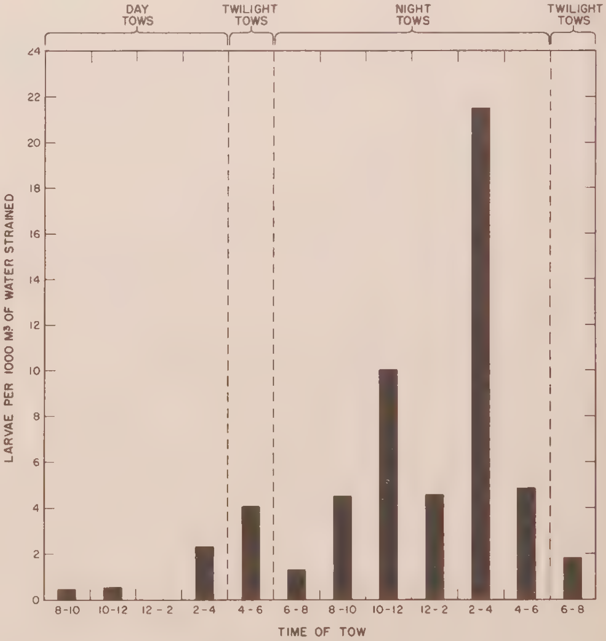

Figure 34.—Larval-tuna catch at various times of the day.

A vertical, diurnal migration of the larvae is suggested in the raw catches and is clearly shown when the surface tows are plotted according to the hour of hauling (fig. 34). (For the present, dodging is not considered; it will be shown later to be relatively unimportant.) Relatively poor catches were experienced during the day, when the larvae presumably were beyond the depth of the surface net. The catches increased after twilight as the larvae apparently migrated to the surface, the greatest catches being made between 10 p. m. and 4 a. m. The catches declined as the downward migration occurred with the approach of daylight.

The depth of the diurnal, vertical migration of

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[2] The following formula was used to compute contamination:

$$\text{Average number of contaminants}=$$

$$\frac{\text{Average time a lower net spent in surface layer}}{\text{Average total elapsed time of tows of the surface net}}\times\text{Average surface catch.}$$

The several amounts were then subtracted from the figures in table 6 and the corrected catches plotted in figure 33.

the tuna larvae cannot be specified, but its maximum can be inferred from our material. A large series of 200-meter oblique hauls in the equatorial region (table 7) shows no statistically significant diurnal variation ($t=1.421$, $P=0.14$), thus suggesting that migration may not occur down to 200 meters. That the migration is of even more limited scope is suggested by the corrected vertical distribution (fig. 33). If migration occurs down to 200 meters, then in the horizontal tows the day catches at the greater depths should be larger than the night catches and also they should be larger than the day catches at the surface. The fact that the subsurface catches are consistently less than the surface day catches suggests a migration which is probably limited to a depth of less than 50 meters, and the main concentration of larvae in the daytime occurred between the levels sampled by the surface and the 50-meter horizontal tows.

Table 7.—*Comparison of day and night catches of tuna larvae by 200-meter oblique tows in equatorial waters*

Time of tow	Number of tows	Larvae/1,000 m.³ of water strained
Day	49	1.50
Night	34	2.23

During the review of vertical migration and vertical distribution the problem of dodging was temporarily disregarded. It must be examined, however, and its effect considered because it can possibly bias comparisons of hauls between depths and between day and night. The presence or absence of dodging can best be examined in the 200-meter oblique tows, assuming that the net had passed through the entire vertical range of larval distribution, thus minimizing or possibly eliminating the effects of vertical migration in the catches. The night catches, although not significantly different from day catches, are about 1.5 times the latter (table 7), suggesting that dodging may have occurred. Even if the relatively greater catches in the night hauls were due to dodging, it will be noted from table 6 that the ratio of night to day catches at the surface is much greater (4.99: 1), suggesting a vertical migration, despite allowances made for the effects of dodging. Additional evidence in favor of vertical migration is provided by the relatively low night-day ratios at greater depths (table 6) as compared with the high ratio of the surface catches.

There is also little evidence in support of dodging when the frequency of captures of the larger larvae are considered, the implication here being that the larger larvae are more capable of dodging the net than are the smaller larvae. In the equatorial area, four larvae 10 mm. or larger were taken during the day and only one at night. In the Hawaiian area only two larvae over 10 mm. were obtained and these were taken at night.

Considering all the evidence, it appears that dodging may alter the catches but not enough to seriously bias our conclusions that most of the larvae live near the surface during both day and night, and that there is a vertical, diurnal migration through relatively shallow depths.

SPECIES COMPOSITION OF THE LARVAL CATCH

Our discussion of species composition is based entirely on catches from the equatorial area between 120° W. longitude and 180°, and 9° N. and 9° S. latitude so that the composition of the larval catch can be compared with that of adults from the same area. Three of the four species of tuna larvae described previously are represented in the plankton samples, while the larvae of two other species of tuna, *Parathunnus sibi* and *Germo alalunga*, either were not taken or were not recognized.

Of the three species of larvae identified (table 8), *A. thazard* constitutes an insignificant portion of the catch, 1.2 percent of the total number of tuna larvae. The *N. macropterus* and *K. pelamis* larvae comprise 22.5 and 59.2 percent, respectively. This is in contrast to the species composition of the longline catch of adults, 73.0 percent of which were *N. macropterus* and 4.4 percent *K. pelamis*. However, the longline catches probably do not provide a reliable estimate of the true abundance of *K.*

Table 8.—*Species composition of larval and adult tunas taken in equatorial waters*

Species	Larvae[1]		Adults[2]	
	Number taken	Percent of total catch	Number taken	Percent of total catch
Neothunnus macropterus	107	22.5	889	73.0
Katsuwonus pelamis	281	59.2	54	4.4
Auxis thazard	6	1.2		
Germo alalunga			68	5.6
Parathunnus sibi			206	16.9
Unidentified	81	17.0		
Total	475		1,217	

[1] Plankton hauls.
[2] Longline catches.

pelamis since the gear is designed and fished with the primary objective of capturing the much-larger, deep-swimming *N. macropterus*. Thus, the low catch figures for *K. pelamis* represent only a few chance catches made by the longline.

The predominance of *K. pelamis* larvae in the plankton catches presents an interesting indication of the probable adult concentration. If we assume that both species have the same fecundity and larval mortality, it would appear that the adult *K. pelamis* population is about two and one-half times that of the *N. macropterus*. However, it is known that the *K. pelamis* ovaries are smaller than the *N. macropterus* ovaries and contain fewer eggs; therefore, this estimate of the relative numerical predominance of *K. pelamis* is minimal. Thus, there is the possibility that a population of *K. pelamis* exists in this region of sufficient size to support a commercial fishery, if the schools can be located. To date, however, only a few schools, consisting mostly of small fish, have been observed and they have occurred mostly in the immediate vicinity of islands and atolls.

AREA AND LOCALITY OF SPAWNING

Most studies of spawning have been based upon observations on the condition of the gonads, and the spawning locality has been assumed to be near the site where females with running or nearly ripe eggs have been captured. This method is applicable to fishes with limited migratory movements or to those that are relatively weak swimmers. However, in the case of the tunas—fishes which possess tremendous swimming speed and range—the actual spawning site could be some distance from the locality in which adult females with nearly ripe gonads are taken. A more-nearly ideal approach to the problem of locating the spawning sites of these fishes would be to examine the less-motile stages in the life cycle, specifically the planktonic eggs and newly hatched larvae.

The present investigation was limited to the larval stages because it has not been possible to identify the eggs of the several tunas. Early larvae can be considered planktonic, and while they have limited powers of movement, it is reasonable to suspect that they do not stray very far from the actual spawning grounds. If this is so, then it can be hypothesized that the localities where tuna larvae are taken should represent the approximate spawning sites.

Three factors must be evaluated before this reasoning can be applied to our data to estimate the location of spawning grounds: (1) The size of the larvae at hatching; (2) the duration of the incubational period, throughout which the eggs are planktonic; and (3) the direction and velocity of the currents.

Determination of size of larvae at hatching.—Sanzo (1932, 1933), who observed the development of the embryo in the eggs of *Orcynus thynnus* and *Orcynus germo*,[3] reported that the larvae measured from 2.44 to 3.04 mm. in total length at hatching. The egg diameters for these two species were from 1.00 to 1.12 mm. for the former, and 0.84 to 0.94 mm. for the latter. Comparatively, the eggs from ripe gonads collected during POFI cruises measured from 0.83 to 1.08 mm. for *N. macropterus*, and from 1.00 to 1.21 mm. for *P. sibi*. *K. pelamis* eggs were from 0.55 to 0.80 mm. in diameter, but it is believed that this may represent a somewhat earlier stage of maturity. The largest egg that Brock (1954) found during his investigation of the biology of *K. pelamis* measured 1.125 mm. in diameter, and should be close to the size of the fully ripe eggs. If egg size has any bearing on size of the larvae at hatching, then newly hatched *N. macropterus* and *K. pelamis* should fall within the size ranges given by Sanzo for two species of tuna, that is, 2.44–3.04 mm.

Determination of duration of incubational period.—The embryonic development of six California fishes (Budd 1940) indicates that various pelagic species have incubational periods ranging from 90 to 264 hours, and that the eyed-embryo stage regularly appears at about the middle of the developmental period or slightly earlier. The latter observation is supported by illustrations presented by Kuntz and Radcliffe (1918) for the pelagic eggs of six species of fish. It seems that the appearance of the eyed-embryo is fixed rather definitely at about the middle of the incubational period. If this holds true for all pelagic eggs, then the incubational period for tunas could be approximated at not more than 4 days, since the eyed-embryo eggs collected by Sanzo (1932, 1933) hatched in less than 2 days.

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[3] Sanzo probably followed Lütken's terminology. If so, *O. thynnus* (Linnaeus) represents "the more or less 'short-finned' genuine tunafish" and *O. germo* (Lacépède) represents the "more or less 'long-finned'" tunas (Lütken 1880). Thus, *O. thynnus* could be bluefin tuna and *O. germo* could be either yellowfin or albacore.

Direction and maximum velocities of currents in the central Pacific.—As stated previously, the North and South Equatorial Currents flow westward and the Equatorial Countercurrent flows eastward in this area. The maximum velocity of the North Equatorial Current during 1950–52 was 0.56 knots, while that of the South Equatorial Current was 1.55 knots, as measured on POFI cruises. The eastward-flowing Countercurrent showed a maximum velocity of 1.16 knots. (Current speed in knots was converted from figures in Cromwell 1951, 1954; Austin 1954; and Stroup 1954.) It is well to bear in mind that the velocity of each current varies considerably throughout the width of the current and at different longitudes (Cromwell 1954, figs. 21 and 27).

The implications in the foregoing discussions are that larvae measuring between 2.44 and 3.04 mm. would have been adrift a maximum of 4 days prior to their hatching, and that these larvae could have drifted westward a distance of about 50 or 150 miles, depending on whether they were in the North or the South Equatorial Current, or they could have drifted eastward a distance of about 100 miles if they were in the Equatorial Countercurrent. The maximum drift in terms of longitudinal distance is about 2½° westward and about 2° eastward.

In the present investigation larvae measuring between 2.50 and 3.90 mm. (which approximates the size of newly hatched larvae), presumed to be *K. pelamis* and *N. macropterus*, were taken at nearly all latitudes from 25° N. to 14½° S. (fig. 35), and also at nearly all longitudes sampled (fig. 36). They were caught at stations which generally were 5 to 10 longitudinal degrees apart and beyond the maximum drift to which these larvae could have been subjected. Thus, the presence of these newly hatched larvae along the various longitudes from 120° W. to 180° provides evidence that some spawning occurs throughout the area sampled.

TIME OF SPAWNING OF *KATSUWONUS PELAMIS* AND *NEOTHUNNUS MACROPTERUS*

Larval-catch data from equatorial waters for the years 1950–52 were segregated by months for each species, and the average catches from three bands of 10° of latitude, 5° N. to 14° N., 5° S. to 4° N., and 14° S. to 6° S. were then plotted to produce figure 37. The area was separated into such bands in order to see if there were seasonal spawning trends from north to south.

The plots show that *K. pelamis* larvae were found throughout the year and in fairly equal numbers each month between 5° N. and 14° N.

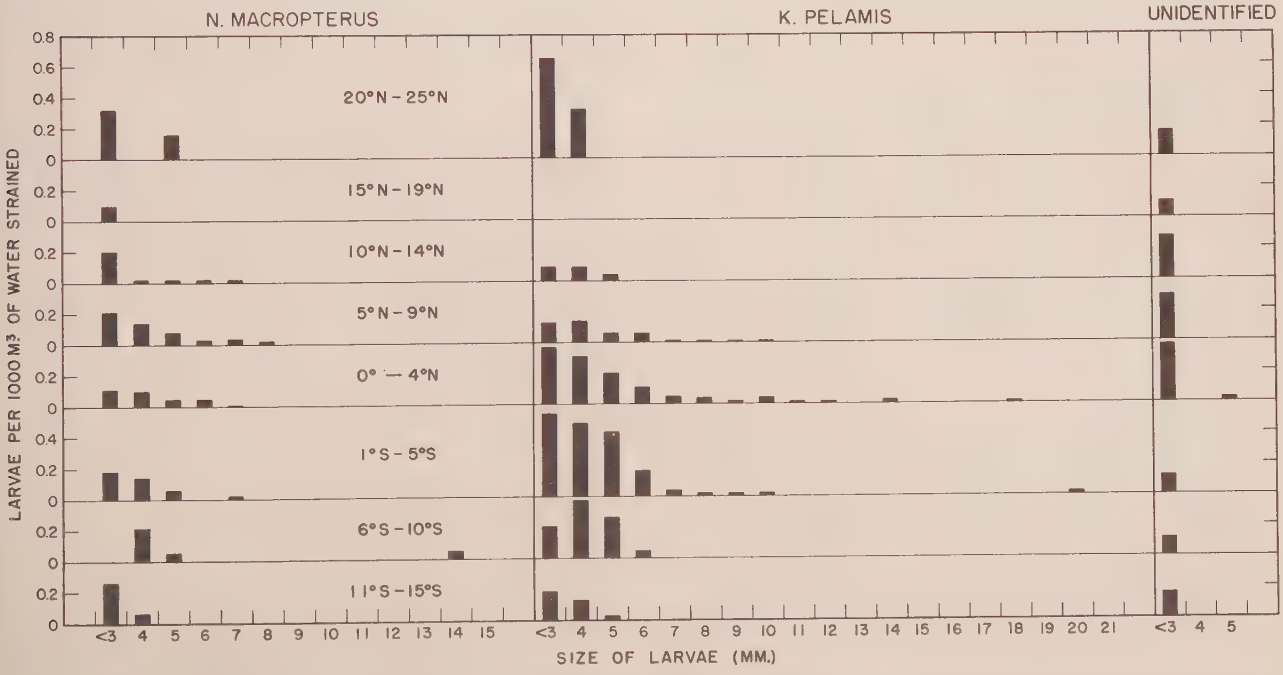

Figure 35.—Latitudinal variation in size composition of tuna larvae caught between 120° W. and 180° longitude.

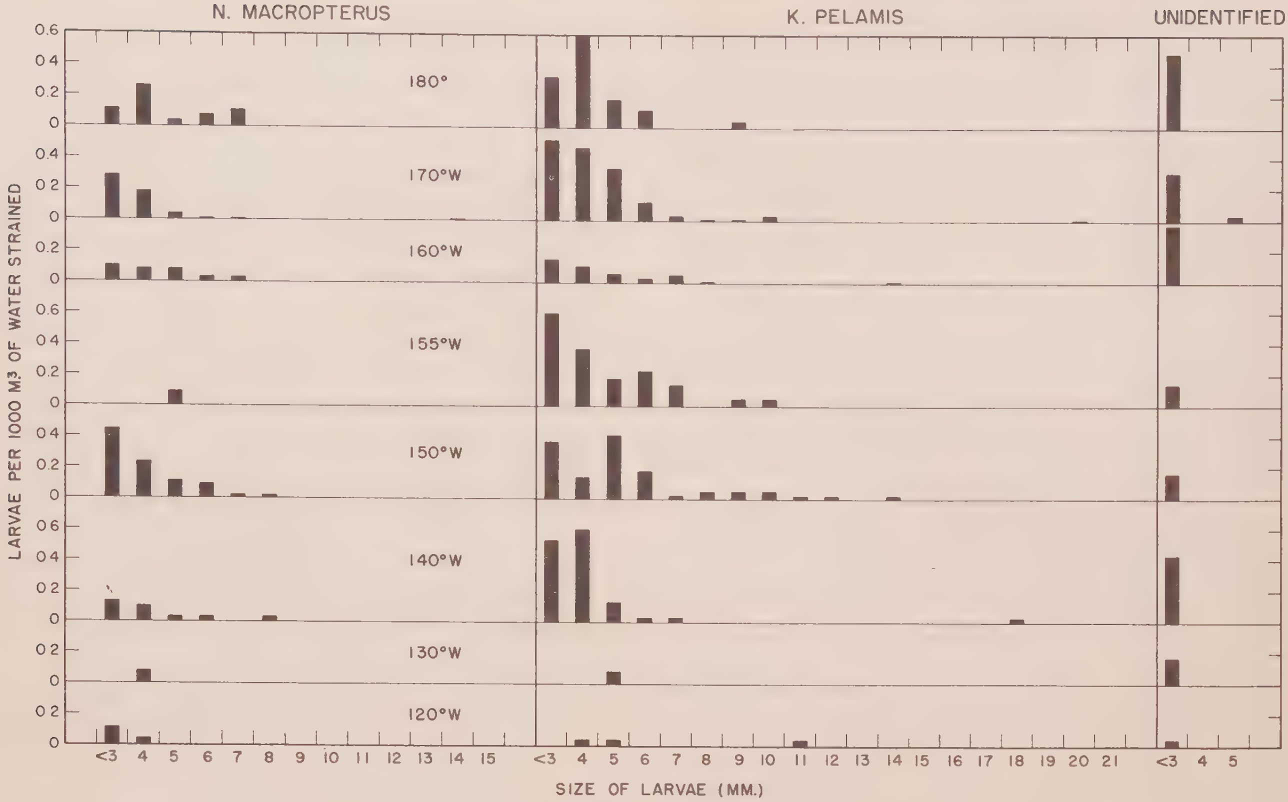

FIGURE 36.—Longitudinal variation in size composition of tuna larvae caught between 14° N. and 14° S. latitude.

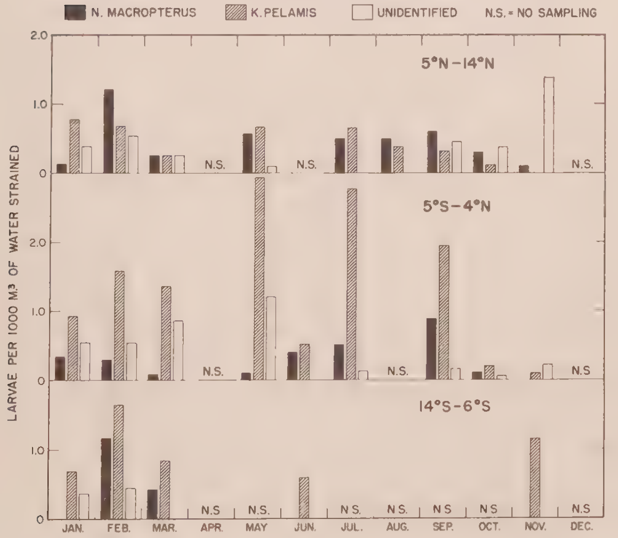

FIGURE 37.—Monthly catches of larvae in equatorial waters for three latitudinal zones, 1950 to 1952.

latitude. Substantially greater numbers of larvae occurred, however, between 4° N. and 5° S. latitude. Although this equatorial region produced *K. pelamis* larvae throughout the year, it showed a definite peak from May through September. South of 6° S. latitude larval *K. pelamis* were rather uniformly abundant; however, the catches do not represent enough months to permit a more specific interpretation. In general, it can be hypothesized that while year-round *K. pelamis* spawning occurs throughout the area between 4° N. and 5° S. latitude, the spawning activity is greatest from May through September.

There are no significant peaks of *N. macropterus* spawning between 14° N. and 5° S. latitude. However, a striking difference exists between the catches of *N. macropterus* and *K. pelamis* larvae in the area south of 5° S. latitude. Here, larvae of the former species were caught only in February and March, none being taken in January, June, and November. Seasonal spawning may occur in more southern waters, but here again data were obtained for too few months to form a definite opinion. As far as *N. macropterus* is concerned, it can be hypothesized that this species spawns throughout the area and throughout the year at a uniform intensity.

SUMMARY

1. Four species of tuna larvae, yellowfin (*Neothunnus macropterus*), skipjack (*Katsuwonus pelamis*), little tunny (*Euthynnus yaito*), and frigate mackerel (*Auxis thazard*), are described from plankton catches taken in central Pacific waters between 23° N. and 15° S. latitude and 120° W. and 180° longitude and from the East Indies and the Gulf of Panama.

2. The most conspicuous, specific characters that distinguish the larvae are as follows:

a. *Neothunnus macropterus:* Absence of chromatophores on the trunk, except over the visceral mass, until the larvae approach 14 mm.

b. *Katsuwonus pelamis:* Presence of a distinct chromatophore on the ventral midline of the caudal region, and no chromatophore at the symphysis of the pectoral girdle.

c. *Euthynnus yaito:* A series of chromatophores along the midventral line of the trunk, from the vicinity of the anal fin base to the caudal region; presence (usually) of a chromatophore at the symphysis of the pectoral girdle.

d. *Auxis thazard:* Three short series of closely set chromatophores on the middorsal, midlateral, and midventral lines of the caudal region; presence (usually) of a chromatophore at the symphysis of the pectoral girdle.

3. Larvae of *Katsuwonus pelamis* and *Neothunnus macropterus* were found in the waters north of the Hawaiian Islands to approximately 25° N. latitude and as far south as the Samoan Islands near 15° S. latitude. The areas rich in larval *Neothunnus macropterus* coincided with the areas where the adults were frequently taken by longlining. Along the Equator, larvae were found between longitudes 120° W. and 180°, the east-west limits of the area investigated, with a decidedly rich area between 140° W. and 180°. The close adult-larva relationship suggests the possibility of a transoceanic distribution of these larvae along the Equator.

4. Larvae were found to be concentrated at or near the surface, especially at night. It seems likely that even in the daytime the bulk of the larvae occur at less than 50 meters. Diurnal migration probably occurs within this shallow zone.

5. The abundance of *Katsuwonus pelamis* larvae in the area implied that a sizeable stock of adult *Katsuwonus pelamis* occurred in equatorial waters.

6. Recently hatched larvae were found in nearly all latitudes, longitudes, and seasons, suggesting widespread, continuous spawning throughout the area sampled.

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APPENDIX

The following tables list by species the number of tuna larvae collected from the POFI research vessel *Hugh M. Smith* on 8 cruises in the equatorial Pacific in 1950–52. The tables include only those cruises or parts of cruises, from which material for this study was obtained.

APPENDIX TABLE 1.—*Tuna larvae collected on* Hugh M. Smith *cruise 5 in equatorial waters*

[All hauls were oblique from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude			*1,000 m.*^{3}					
No. 1	27°00′ N.	175°11′ W.	6-30-50	0945	1.25	----	----	----	----	----
No. 2	25°00′ N.	174°10′ W.	7- 1-50	0258	1.32	1	1	----	----	2
No. 3	22°58′ N.	173°00′ W.	7- 1-50	2315	1.34	----	----	----	----	----
No. 4	21°00′ N.	172°00′ W.	7- 2-50	0415	0.74	----	3	----	----	3
No. 5	19°00′ N.	171°52′ W.	7- 3-50	0807	1.25	----	----	----	----	----
No. 6	17°01′ N.	171°46′ W.	7- 3-50	1219	1.43	----	----	----	----	----
No. 7	15°00′ N.	171°54′ W.	7- 4-50	1649	0.89	----	----	----	1	1
No. 8	14°00′ N.	171°57′ W.	7- 5-50	0123	0.85	1	----	----	1	2
No. 9	13°00′ N.	172°01′ W.	7- 5-50	0950	1.33	----	----	----	----	----
No. 10	12°00′ N.	172°00′ W.	7- 5-50	1815	0.88	----	----	----	----	----
No. 11	11°03′ N.	172°00′ W.	7- 6-50	0315	1.33	----	3	----	----	3
No. 12	9°54′ N.	172°02′ W.	7- 6-50	1213	1.78	1	----	----	----	1
No. 13	8°54′ N.	172°00′ W.	7- 6-50	2012	1.19	2	----	----	----	2
No. 14	7°59′ N.	171°57′ W.	7- 7-50	0350	1.62	1	4	----	----	5
No. 15	6°59′ N.	171°46′ W.	7- 7-50	1226	1.58	1	----	----	----	1
No. 16	6°02′ N.	171°56′ W.	7- 7-50	2130	1.38	----	2	----	----	2
No. 17	5°00′ N.	172°02′ W.	7- 8-50	0845	1.82	1	----	----	----	1
No. 18	4°00′ N.	172°03′ W.	7- 8-50	1659	1.35	----	----	----	----	----
No. 19	3°00′ N.	172°01′ W.	7- 9-50	0036	1.06	----	1	----	----	1
No. 20	2°00′ N.	171°53′ W.	7- 9-50	0838	1.81	----	----	----	1	1
No. 21	0°54′ N.	172°12′ W.	7- 9-50	1746	1.59	2	1	2	2	7
No. 22	0°08′ S.	172°02′ W.	7-10-50	0143	1.94	----	8	----	----	8
No. 23	1°00′ S.	171°57′ W.	7-10-50	0925	1.26	----	24	----	----	24
No. 24	2°00′ S.	171°55′ W.	7-10-50	1740	1.41	----	----	----	----	----
No. 25	2°59′ S.	171°59′ W.	7-11-50	0133	1.31	1	17	----	----	18
No. 26	4°05′ S.	171°56′ W.	7-11-50	1055	1.58	9	2	----	----	11
No. 27	5°04′ S.	171°58′ W.	7-11-50	2110	1.63	----	----	----	----	----
No. 28	4°56′ S.	158°02′ W.	7-28-50	0556	1.38	----	----	----	----	----
No. 29	4°00′ S.	158°03′ W.	7-28-50	1324	0.64	----	----	----	----	----
No. 30	3°03′ S.	158°00′ W.	7-28-50	2137	0.87	----	----	----	----	----
No. 31	2°03′ S.	158°00′ W.	7-29-50	0550	0.65	----	----	----	----	----
No. 32	1°00′ S.	158°01′ W.	7-29-50	1418	1.00	----	1	----	----	1
No. 33	0°02′ S.	157°58′ W.	7-29-50	2221	0.77	----	----	----	----	----
No. 34	0°57′ N.	157°57′ W.	7-30-50	0646	1.53	----	----	----	----	----
No. 35	2°00′ N.	158°07′ W.	7-30-50	1532	0.85	----	1	----	----	1
No. 36	3°00′ N.	157°58′ W.	7-30-50	2302	0.97	----	6	----	----	6
No. 37	4°00′ N.	158°03′ W.	7-31-50	0640	1.65	----	6	----	----	6
No. 38	5°00′ N.	158°00′ W.	7-31-50	1750	1.18	----	1	----	----	1
No. 39	6°00′ N.	157°57′ W.	8- 1-50	0144	1.31	1	----	----	----	1
No. 40	7°00′ N.	157°57′ W.	8- 1-50	0854	0.95	----	----	----	----	----
No. 41	8°00′ N.	157°50′ W.	8- 1-50	1620	3.36	1	----	----	----	1
No. 42	9°00′ N.	157°55′ W.	8- 2-50	0020	1.14	2	1	----	----	3
No. 43	10°00′ N.	157°53′ W.	8- 2-50	0744	1.60	1	2	----	----	3
No. 44	11°00′ N.	157°55′ W.	8- 2-50	1546	1.14	----	----	----	----	----
No. 45	11°59′ N.	158°04′ W.	8- 2-50	2343	1.03	1	4	----	----	5
No. 46	13°00′ N.	157°58′ W.	8- 3-50	0800	1.46	----	1	----	----	1
No. 47	14°00′ N.	157°54′ W.	8- 3-50	1639	1.31	----	----	----	----	----
No. 48	14°58′ N.	157°55′ W.	8- 4-50	0253	0.59	2	----	----	----	2
No. 49	17°00′ N.	158°08′ W.	8- 4-50	1741	0.93	----	----	----	----	----
No. 50	19°02′ N.	157°59′ W.	8- 5-50	1006	1.03	----	----	----	----	----
No. 51	20°53′ N.	158°02′ W.	8- 5-50	2300	0.85	3	2	2	----	7

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[1] +11 zone time on stations 1 to 27; + 10 zone time on stations 28 to 51.

APPENDIX TABLE 2.—*Tuna larvae collected on* Hugh M. Smith *cruise 6 in Hawaiian waters*

[All hauls were 1-hour horizontal tows at depth indicated]

Station	Depth of haul	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
		North latitude	West longitude								
	Meters					*1,000 m.³*					
No. 1	0	23°31′	161°05.5′	8-25-50	1405	2.05	1				1
	50					1.99	1	1			2
	150					3.14				1	1
No. 1A	0	22°45′	161°15′	8-25-50	2030	2.63	5	9	1	4	19
	50					2.81		2		3	5
	150					3.32				3	3
No. 2	0	21°57′	161°05′	8-26-50	0315	2.26	12				12
	100					3.07		3		1	4
	200					4.01	1	1			2
No. 3	0	21°09.5′	161°03′	8-26-50	1042	2.15					
	50					2.07				1	1
	150					2.60					
No. 4	0	20°20′	161°05′	8-26-50	1750	2.25		8		5	13
	100					2.80		1			1
	200					3.57		1			1
No. 5	0	19°25.5′	161°05′	8-27-50	0042	2.31	2	13		10	25
	150					3.11					
	300					3.70		1		1	2
No. 6	0	19°26′	159°50′	8-27-50	0950	2.39	2				2
	100					2.48					
	200					3.98					
No. 7	0	20°16.5′	159°44′	8-27-50	1853	3.03	4		1		5
	50					3.22		3			3
	150					4.30	1	1			2
No. 8	0	20°54′	159°47′	8-28-50	0507	2.84		5	1	2	8
	100					2.66					
	200					3.68	1	4	3		8
No. 9	0	21°05.1′	159°50.5′	8-28-50	1350	2.46					
	50					2.49				1	1
	150					3.06					
No. 10	0	22°48.5′	159°51′	8-24-50	2239	2.33	10	21	2	22	55
	150					3.61		3	7		10
	300					5.80	2	5	1	1	9
No. 11	0	23°27′	159°45.7′	8-25-50	0500	2.37	5	9	2		16
	50					2.85				1	1
	150					4.21					
No. 12	0	22°43.3′	158°26′	8-24-50	1250	2.71					
	100					2.90					
	200					3.95					
No. 13	0	21°50′	158°30.6′	8-24-50	0528	2.01	4		7	3	14
	50					3.14	2	10	4	6	22
	150					3.56		2	1	2	5
No. 14	0	20°50′	158°32′	8-18-50	1720	2.29	11			2	13
	100					2.17	2				2
	200					2.25				1	1
No. 15	0	20°15′	158°24′	8-19-50	2340	2.72	5	8			13
	150					3.81		1			1
	300					5.28	2	4			6
No. 16	0	19°24′	158°23′	8-19-50	0750	3.38	3				3
	100					3.48					
	200					3.06	1	6			7
No. 17	0	18°30′	158°29′	8-19-50	1522	2.24				1	1
	100					3.31					
	150					4.09					
No. 18	0	18°22′	157°07.5′	8-20-50	0210	1.61	13	22		11	46
	100					2.43	2				2
	200					3.61	1	5		3	9
No. 19	0	19°31′	157°10′	8-20-50	2311	2.73	1				1
	100					3.93		1			1
	150					4.78	1	2			3
No. 20	0	20°23′	157°07′	8-21-50	0815	2.11				1	1
	150					3.15		1			1
	300					4.29		1			1
No. 21	0	20°55.5′	157°10.3′	8-21-50	1412	2.77	7				7
	100					2.45	1				1
	150					2.81					
No. 22	0	21°50′	157°10.5′	8-23-50	1754	2.59		1		1	2
	100					3.07				1	1
	200					4.07		1			1
No. 23	0	22°39′	157°13′	8-23-50	1020	2.84				1	1
	50					2.99					
	150					3.64					
No. 24	0	22°40′	155°47′	8-22-50	2149	2.90	1			1	2
	100					3.34					
	200					5.03	1	3			4
No. 25	0	21°56.3′	155°45.3′	8-22-50	1500	2.82	14				14
	150					3.43					
	300					3.92	1	1			2
No. 26	0	21°03.5′	155°50′	8-22-50	0711	2.11	6				6
	100					3.07				1	1
	200					4.69				2	2
No. 27	0	20°30′	155°47.2′	8-22-50	0140	2.18	6	4		2	12
	50					2.30					
	150					3.88					
No. 28	0	18°32.5′	156°07′	8-20-50	1136	2.22				3	3
	100					2.58					
	200					4.08				1	1

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[1] Local civil time corresponding to +10 zone time.

APPENDIX TABLE 3.—*Tuna larvae collected on* Hugh M. Smith *cruise 7 in equatorial waters*

[All hauls were oblique tows from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude								
					1,000 m.³					
No. 1	20°30′ N.	158°00′ W.	10-17-50	1925	0.95					
No. 2	19°10′ N.	158°02′ W.	10-18-50	0532	0.90				2	2
No. 3	18°13′ N.	158°00′ W.	10-18-50	1326	1.11					
No. 4	17°10′ N.	158°00′ W.	10-18-50	2159	0.68					
No. 5	16°11′ N.	157°57′ W.	10-19-50	0506	0.70	(2)	(2)	(2)	(2)	(2)
No. 6	15°02′ N.	157°58′ W.	10-19-50	1250	1.00					
No. 7	14°03′ N.	157°59′ W.	10-19-50	1921	1.22				3	3
No. 8	12°57′ N.	157°57′ W.	10-20-50	0330	0.73					
No. 9	12°25′ N.	158°00′ W.	10-20-50	1729	1.22					
No. 10	11°08′ N.	158°01′ W.	10-21-50	1526	1.37					
No. 11	10°01′ N.	157°55′ W.	10-22-50	0724	1.43					
No. 12	8°52′ N.	157°45′ W.	10-23-50	0742	0.96					
No. 13	8°05′ N.	157°15′ W.	10-24-50	0742	1.41				2	2
No. 14	7°17′ N.	157°04′ W.	10-25-50	0727	1.70					
No. 15	5°57′ N.	157°05′ W.	10-26-50	0737	1.57				1	1
No. 16	5°19′ N.	157°20′ W.	10-27-50	0725	2.21	1	1		3	5
No. 17	4°23′ N.	157°30′ W.	10-28-50	0912	1.87		2			2
No. 18	3°17′ N.	157°53′ W.	10-29-50	0802	1.31				1	1
No. 19	2°01′ N.	157°34′ W.	11- 1-50	0812	1.59		1			1
No. 20	6°07′ N.	162°06′ W.	11- 6-50	0950	1.93					
No. 21	6°13′ N.	163°05′ W.	11- 7-50	0810	1.57				1	1
No. 22	6°59′ N.	163°54′ W.	11- 8-50	0808	1.75				4	4
No. 23	7°24′ N.	164°25′ W.	11- 9-50	0806	1.44					
No. 24	6°31′ N.	165°45′ W.	11-10-50	0813	1.52	1			10	11

[1] +10 zone time on stations 1 to 21; +11 zone on stations 22 to 24.

[2] Sample missing.

APPENDIX TABLE 4.—*Tuna larvae collected on* Hugh M. Smith *cruise 8 in equatorial waters*

[All hauls were oblique tows from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude								
					1,000 m.³					
No. 1	20°48′ N.	157°30′ W.	1-14-51	2012	0.94				1	1
No. 2	18°47′ N.	158°01′ W.	1-15-51	1449	0.63					
No. 4	14°30′ N.	158°00′ W.	1-17-51	0925	0.43				3	3
No. 6	12°57′ N.	157°58′ W.	1-17-51	2251	0.82					
No. 7	11°59′ N.	157°50′ W.	1-18-51	0811	1.36					
No. 8	11°00′ N.	157°53′ W.	1-18-51	1633	1.40				3	3
No. 9	10°00′ N.	157°56′ W.	1-19-51	0224	1.83	2				2
No. 10	9°00′ N.	157°58′ W.	1-19-51	1154	0.99					
No. 11	8°04′ N.	157°58′ W.	1-19-51	2024	1.24		3			3
No. 12	7°08′ N.	157°58′ W.	1-20-51	0615	1.30					
No. 13	5°59′ N.	158°00′ W.	1-20-51	1505	1.81					
No. 14	5°00′ N.	158°00′ W.	1-20-51	2338	0.98					
No. 15	3°55′ N.	157°54′ W.	1-21-51	1100	0.98					
No. 16	3°02′ N.	157°57′ W.	1-21-51	2135	1.02	1				1
No. 17	2°00′ N.	158°01′ W.	1-21-51	0802	1.63				1	1
No. 18	0°58′ N.	158°07′ W.	1-22-51	1730	1.53					
No. 19	0°01′ N.	158°02′ W.	1-23-51	0328	1.93					
No. 20	0°55′ S.	157°54′ W.	1-23-51	1208	1.51		1			1
No. 21	2°00′ S.	158°00′ W.	1-23-51	2312	1.27	1				1
No. 22	3°00′ S.	158°05′ W.	1-24-51	0744	1.27	1			1	2
No. 23	4°00′ S	158°00′ W.	1-24-51	1550	1.07					
No. 24	5°00′ S.	158°00′ W.	1-24-51	2330	0.89	5				5
No. 25	6°01′ S.	158°06′ W.	1-25-51	0741	1.23		2		1	3
No. 26	7°00′ S.	158°01′ W.	1-25-51	1548	1.35					
No. 77	14°30′ S.	171°51′ W.	2. 26-51	1931	1.88	6	8		4	18
No. 78	11°56′ S.	171°59′ W.	2-27-51	1129	1.92	4	2		1	7
No. 79	10°05′ S.	171°52′ W.	2-28-51	0245	1.74	2	5		1	8
No. 80	8°00′ S.	171°56′ W.	2-28-51	1821	1.45		2			2
No. 81	7°01′ S.	171°54′ W.	3- 1-51	0238	1.05		2			2
No. 82	5°59′ S.	172°00′ W.	3- 1-51	1118	1.40	1				1
No. 83	5°00′ S.	172°15′ W.	3- 1-51	1930	1.51					
No. 84	4°00′ S.	172°06′ W.	3- 2-51	0735	1.51		4			4
No. 85	3°00′ S.	171°50′ W.	3- 2-51	1537	1.51	1	1		2	4
No. 86	2°00′ S.	172°02′ W.	3- 3-51	1612	1.59					
No. 87	0°57′ S.	172°00′ W.	3- 4-51	0047	1.39		1		1	2
No. 88	0°09′ N.	171°58′ W.	3- 4-51	0926	1.07		1		1	2
No. 89	1°04′ N.	172°00′ W.	3- 4-51	1702	0.98		1		2	3
No. 90	1°54′ N.	172°02′ W.	3- 5-51	0034	1.85		8		5	13
No. 91	2°48′ N.	172°04′ W.	3- 5-51	0834	1.33		3		1	4
No. 92	3°57′ N.	172°02′ W.	3- 5-51	1816	1.22					
No. 93	4°56′ N.	171°54′ W.	3- 6-51	0249	1.62	1	1			2
No. 94	5°55′ N.	171°50′ W.	3- 6-51	1105	1.43	1	1		1	3
No. 95	6°58′ N.	171°49′ W.	3- 6-51	1939	1.91		2			2
No. 96	7°56′ N.	171°51′ W.	3- 7-51	0407	1.50					
No. 97	9°00′ N.	171°58′ W.	3- 7-51	1315	1.54	1				1
No. 98	10°02′ N.	171°56′ W.	3- 7-51	2147	1.54					
No. 99	11°02′ N.	171°52′ W.	3- 8-51	0602	1.58				1	1
No. 100	12°00′ N.	171°52′ W.	3- 8-51	1417	1.51				2	2
No. 101	13°01′ N.	171°48′ W.	3- 8-51	2236	1.72	1				1
No. 102	13°58′ N.	171°24′ W.	3- 9-51	0650	1.27					
No. 103	15°00′ N.	170°52′ W.	3- 9-51	1557	1.31					
No. 104	16°58′ N.	169°42′ W.	3-10-51	0913	1.99				1	1
No. 105	18°58′ N.	168°27′ W.	3-11-51	0207	1.94					

[1] +10 zone time on stations 1 to 26; +11 zone time on stations 77 to 105.

APPENDIX TABLE 5.—*Tuna larvae collected on* Hugh M. Smith *cruise 11 in equatorial waters*

[All hauls were oblique tows from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude								
					1,000 m.^{3}					
No. 1	14°37′ N.	150°12′ W.	8-24-51	0854	1.44		1			1
No. 2	13°06′ N.	149°58′ W.	8-25-51	0828	1.22					
No. 3	11°31′ N.	150°02′ W.	8-26-51	0832	1.90					
No. 4	9°41′ N.	150°01′ W.	8-27-51	0801	1.36	2				2
No. 5	8°58′ N.	150°08′ W.	8-28-51	0722	1.85					
No. 6	7°59′ N.	149°51′ W.	8-29-51	0754	2.84	2	1			3
No. 7	6°55′ N.	149°50′ W.	8-30-51	0734	1.69					
No. 8	5°59′ N.	149°55′ W.	8-31-51	0742	1.54	4				4
No. 9	4°49′ N.	150°02′ W.	9- 1-51	0743	1.95	4	1			5
No. 10	4°02′ N.	150°04′ W.	9- 2-51	0852	0.70	2	1		2	5
No. 11	2°55′ N.	150°09′ W.	9- 3-51	0739	1.70	7	6			13
No. 12	1°59′ N.	150°04′ W.	9- 4-51	0740	1.94	2	1			3
No. 22	2°00′ N.	151°18′ W.	9-19-51	0743	1.29	3	2			5
No. 23	0°55′ N.	149°54′ W.	9-20-51	0742	1.31	1	1			2
No. 24	0°01′ S.	149°56′ W.	9-21-51	0743	1.47		2			2
No. 25	1°03′ S.	150°16′ W.	9-22-51	0746	1.13					
No. 26	2°01′ S.	150°08′ W.	9-23-51	0737	1.19		2		1	3
No. 27	3°34′ S.	150°05′ W.	9-24-51	0740	1.55		3			3
No. 28	4°57′ S.	150°04′ W.	9-25-51	0906	1.34					
No. 29	4°00′ S.	150°00′ W.	9-25-51	2352	1.88		21			21
No. 30	3°00′ S.	149°57′ W.	9-26-51	0858	1.64					
No. 31	2°00′ S.	150°02′ W.	9-26-51	1719	1.39		7		1	8
No. 32	1°00′ S.	149°58′ W.	9-27-51	0210	1.51	(2)	(2)	(2)	(2)	(2)
No. 33	0°02′ N.	150°00′ W.	9-27-51	1300	1.12	1	1			2
No. 34	1°02′ N.	150°01′ W.	9-27-51	2332	1.57	(2)	(2)	(2)	(2)	(2)
No. 35	2°01′ N.	149°53′ W.	9-28-51	0840	1.54	1				1
No. 36	3°00′ N.	150°03′ W.	9-28-51	1715	1.63	1	1			2
No. 37	3°58′ N.	150°00′ W.	9-29-51	0152	1.53	2	3			5
No. 38	4°59′ N.	149°56′ W.	9-29-51	1038	1.07		1			1
No. 39	5°56′ N.	150°00′ W.	9-29-51	1919	1.66					
No. 40	6°51′ N.	149°57′ W.	9-30-51	0343	1.63	3				3
No. 41	7°51′ N.	150°57′ W.	9-30-51	1257	1.93		1		3	4
No. 42	8°57′ N.	149°58′ W.	9-30-51	2233	1.47	1	1			2
No. 43	10°00′ N.	150°13′ W.	10- 1-51	0709	1.79		1			1
No. 44	10°58′ N.	150°02′ W.	10- 1-51	1554	1.73					
No. 45	11°59′ N.	150°03′ W.	10- 2-51	0042	1.47					
No. 46	13°00′ N.	149°56′ W.	10- 2-51	0907	1.60	4				4
No. 47	14°01′ N.	150°03′ W.	10- 2-51	1733	1.78					
No. 48	15°02′ N.	150°01′ W.	10- 3-51	0144	1.60	(2)	(2)	(2)	(2)	(2)
No. 49	17°00′ N.	150°42′ W.	10- 3-51	1653	1.94					
No. 50	19°00′ N.	151°19′ W.	10- 4-51	0750	1.97					

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[1] +10 zone time on all stations.

[2] No sample.

APPENDIX TABLE 6.—*Tuna larvae collected on* Hugh M. Smith *cruise 14 in equatorial waters*

[All hauls were oblique tows from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude								
					1,000 m.³					
No. 1	7°57′ N.	154°57′ W.	1-27-52	1158	1.01					
No. 2	6°55′ N.	154°57′ W.	1-27-52	2132	1.33		9			9
No. 3	5°53′ N.	154°55′ W.	1-28-52	0813	1.13					
No. 4	4°55′ N.	154°51′ W.	1-28-52	1707	1.53		1		1	2
No. 5	3°54′ N.	154°51′ W.	1-29-52	0207	1.32					
No. 6	2°56′ N.	154°59′ W.	1-29-52	1057	1.03					
No. 7	1°54′ N.	155°03′ W.	1-29-52	2010	1.15		1		1	2
No. 8	0°54′ N.	155°11′ W.	1-30-52	0837	1.33		1			1
No. 9	0°06′ S.	155°14′ W.	1-30-52	1905	2.05		14		1	15
No. 10	1°10′ S.	155°08′ W.	1-31-52	0452	1.65		2			2
No. 11	2°00′ S.	155°03′ W.	1-31-52	1200	1.48					
No. 12	3°00′ S.	154°58′ W.	1-31-52	2124	1.51	1	4			5
No. 13	4°00′ S.	155°07′ W.	2- 1-52	0707	1.39					
No. 14	4°58′ S.	155°00′ W.	2- 1-52	1920	1.25	1	3			4
No. 15	5°53′ S.	155°03′ W.	2- 2-52	0455	1.33					
No. 16	6°50′ S.	155°05′ W.	2- 2-52	1407	1.32					
No. 17	7°56′ S.	179°53′ W.	2-15-52	0116	1.89		2			2
No. 18	7°01′ S.	179°49′ W.	2-15-52	1053	1.67		3			3
No. 19	6°05′ S.	179°58′ W.	2-15-52	1800	1.55	3				3
No. 20	5°04′ S.	179°58′ W.	2-16-52	0529	1.76	1	7			8
No. 21	4°03′ S.	179°58′ W.	2-16-52	1506	1.31	2	8			10
No. 22	2°56′ S.	180°00′	2-17-52	0040	1.39	1	2			3
No. 23	1°52′ S.	179°54′ E.	2-17-52	1107	1.34					
No. 24	0°59′ S.	179°57′ E.	2-17-52	1932	1.64		1			1
No. 25	0°52′ N.	179°59′ E.	2-18-52	0520	1.21		2		3	5
No. 26	1°03′ N.	179°58′ W.	2-18-52	1615	1.51			1	4	5
No. 27	2°07′ N.	179°57′ W.	2-19-52	0210	1.07					
No. 28	3°06′ N.	179°57′ W.	2-19-52	1105	1.74					
No. 29	4°05′ N.	179°55′ W.	2-19-52	2008	1.47		4	1	2	7
No. 30	5°06′ N.	179°50′ W.	2-20-52	0505	1.70	4	4		1	9
No. 31	6°06′ N.	179°44′ W.	2-20-52	0211	1.45	2				2
No. 32	7°04′ N.	179°59′ E.	2-20-52	1108	1.61	3	1		3	7
No. 33	8°03′ N.	179°58′ W.	2-21-52	0759	1.39					
No. 34	8°54′ N.	179°55′ W.	2-21-52	1720	1.33					

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[1] +10 zone time on stations 1 to 16; +12 zone time on stations 17 to 34.

APPENDIX TABLE 7.—*Tuna larvae collected on* Hugh M. Smith *cruise 15 in equatorial waters*

[All hauls were oblique tows from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude								
					1,000 m.³					
No. 1	8°59′ N.	139°56′ W.	5-28-52	0731	1.42					
No. 2	7°51′ N.	139°46′ W.	5-28-52	1839	1.62					
No. 3	7°00′ N.	140°00′ W.	5-29-52	0315	1.73			1		1
No. 4	6°36′ N.	139°44′ W.	5-29-52	1035	1.87					
No. 5	6°00′ N.	140°00′ W.	5-29-52	1727	2.06	4				4
No. 6	5°02′ N.	139°58′ W.	5-30-52	0208	1.90	2	7		1	10
No. 7	4°05′ N.	139°58′ W.	5-30-52	1003	2.17	1	10		2	13
No. 8	3°09′ N.	139°53′ W.	5-30-52	1838	1.51		10		10	20
No. 9	1°57′ N.	140°03′ W.	5-31-52	0344	2.46		8			8
No. 10	0°53′ N.	140°02′ W.	5-31-52	1237	1.70		1			1
No. 11	0°11′ S.	139°52′ W.	5-31-52	2138	2.06					
No. 12	1°02′ S.	139°52′ W.	6- 1-52	0515	1.95					
No. 13	2°00′ S.	139°50′ W.	6- 1-52	1257	1.57					
No. 14	3°00′ S.	139°52′ W.	6- 1-52	2026	1.52	1	3			4
No. 15	4°00′ S.	140°05′ W.	6- 2-52	0628	1.32	1	1			2
No. 16	5°30′ S.	139°57′ W.	6- 2-52	1839	1.36	1				1
No. 17	7°00′ S.	139°58′ W.	6- 3-52	0709	1.72		1			1

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[1] +9 zone time on all stations.

APPENDIX TABLE 8.—*Tuna larvae collected on* Hugh M. Smith *cruise 18 in equatorial waters*

[All hauls were oblique tows from 0 to 200 meters, of 30 minutes' duration]

Station	Position		Date	Time started [1]	Water strained	*Neothunnus macropterus*	*Katsuwonus pelamis*	*Auxis thazard*	Unidentified	Total
	Latitude	Longitude								
					1,000 $m.^3$					
No. 2	9°00′ N.	120°50′ W.	10-19-52	0012	1.53					
No. 4	7°06′ N.	120°00′ W.	10-21-52	0200	1.24	2			2	4
No. 5	5°50′ N.	120°16′ W.	10-22-52	0217	3.29	2	1			3
No. 6	4°53′ N.	119°59′ W.	10-22-52	2325	1.45	1	1			2
No. 7	4°01′ N.	120°06′ W.	10-23-52	1200	1.53					
No. 8	3°03′ N.	120°05′ W.	10-25-52	0004	1.54	1				1
No. 9	1°55′ N.	120°14′ W.	10-26-52	0105	3.05					
No. 10	1°02′ N.	120°17′ W.	10-27-52	0111	1.46					
No. 11	0°39′ N.	120°14′ W.	10-28-52	0115	2.62					
No. 13	1°04′ S.	120°07′ W.	10-28-52	2309	1.62					
No. 15	3°06′ S.	120°10′ W.	10-29-52	2310	1.36					
No. 17	4°50′ S.	120°21′ W.	10-31-52	1206	0.77					
No. 19	6°37′ S.	120°24′ W.	10-31-52	2307	1.37					
No. 21	8°40′ S.	120°35′ W.	11- 1-52	2308	0.88		1			1
No. 24	4°12′ S.	130°14′ W.	11- 5-52	2311	0.87		1			1
No. 26	2°15′ S.	130°11′ W.	11- 6-52	2310	1.12					
No. 28	0°27′ S.	130°09′ W.	11- 7-52	2310	1.31					
No. 30	1°10′ N.	130°08′ W.	11- 9-52	0103	2.33					
No. 31	1°42′ N.	130°22′ W.	11- 9-52	2329	1.31			1		1
No. 32	3°15′ N.	130°14′ W.	11-11-52	0005	1.40				2	2
No. 33	4°37′ N.	130°26′ W.	11-12-52	0015	0.71					
No. 34	5°42′ N.	130°50′ W.	11-12-52	2308	0.87					
No. 36	7°56′ N.	131°11′ W.	11-14-52	0002	1.18					
No. 37	9°12′ N.	131°24′ W.	11-15-52	0103	0.60					

[1] +8 zone time on all stations.

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NOTES

An Unusually Large Salp

A large example of *Thetys vagina* Tilesius, solitary form, was captured in a 1-meter (mouth diameter) closing-type plankton net at a depth between 120 and 170 meters by the Pacific Oceanic Fishery Investigations, U. S. Fish and Wildlife Service, on February 5, 1956, at 22° 15′N. latitude, 157°46′W. longitude. The specimen measured 306 mm. in length without proccesses and 333 mm. with processes. By water displacement its total volume equalled 278 ml.

This specimen is apparently larger than any salp previously known and is therefore considered worthy of note. The largest salps previously reported have had lengths as follows: *Thetys vagina*, solitary form, 226 mm. (Traustedt, 1885. *K. Danske Vidensk. Selsk., Skr., Naturv. og. Math. Afd.* 2(8): 337–400 [as *Salpa costata-tilesii*]); *Helicosalpa komaii* (Ihle and Ihle-Landenberg), solitary form, 230 mm. (Komai, 1932. *Kyoto Univ., Col. Sci., Mem.*, Ser. B. 8(1): 65 80 [as *Salpa virgula*]); *Salpa maxima* Forskål, solitary form, 230 mm. (Thompson, 1948. *Pelagic Tunicates of Australia.* Commenwealth Council for Scientific and Industrial Research, Melbourne. 196 pp.). In volume the largest specimen previously reported was a solitary form of *Helicosalpa virgula* (Vogt), 141 mm. in length, which measured 158 ml. in total volume by water displacement (Yount, 1954. *Pacific Sci.* 8(3): 276–330).

The nomenclature used in this note follows that of Yount (*ibid.*).—*Eugene L. Nakamura, Pacific Oceanic Fishery Investigations, U. S. Fish and Wildlife Service, Honolulu, Hawaii, and James L. Yount, Dept. of Biology, University of Florida, Gainesville, Florida.*

TUNA MEAT PIGMENT STUDIES

Spectral Reflectance Studies of the Heme Pigments in Tuna Fish Flesh. Some Characteristics of the Pigments and Discoloration of Tuna Meat

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During investigations on the "greening" in certain yellowfin tuna on precooking, information regarding the characteristics and reactions of the heme pigments in tuna meat was revealed, largely through application of the technique of spectral reflectance. Spectral evidence indicated a predominance of hemoglobin rather than myoglobin in the flesh pigments, an increase in methemoglobin and denaturation on storage, and a greater solubility of methemoglobin in aqueous media in contrast to oxyhemoglobin. Greening is an actual color condition due to an anomalous heme protein oxidation. Related are high concentrations of methemoglobin, some denaturation, and a slightly high fat peroxide content in the raw meat. Oxygen starvation due to the exhaustion of the fish during landing does not appear to produce factors that lead to greening, but changes that occur even in the frozen state seem to be responsible.

The discoloration of meatstuffs is a problem familiar to the packers and processors of such products. Present knowledge of the cause and probable mechanisms producing a variety of such conditions has been summarized by Watts (*24*). One similar off-color variation recognized in fish meat is the undesirable "green" color that develops in the flesh of certain tuna on precooking, prior to canning, and results in considerable economic loss to the fisherman and to the industry (*19*).

The problem has been the subject of intensive research by the Japanese (*16*). Matsuzaka and Takahashi (*15*) have reported a correlation between the greening of tuna and the concentration of a flesh pigment identified spectrophotometrically by them as myoglobin. More recently Brown, Tappel, and Olcott (*5*) have reported on work which indicates that the pigment responsible for greening is a hemichrome.

The advantages of spectral reflectance applied to biochemical problems have been pointed out (*4, 18*). Application of this method to the present investigation was obvious, because it made possible the study of the normal or anomalous protein pigments in raw and cooked flesh, and of the changes induced by the variation of experimental conditions.

Materials and Methods

Samples used in this research were carefully trimmed sections of the loins of yellowfish tuna (70 to 200 pounds), *Neothunnus macropterus* (Temminck and Schlegel), caught on long line by research vessels of the Pacific Oceanic Fishery Investigations of the U. S. Fish and Wildlife Service in the central equatorial Pacific. The fish were frozen on board, as soon as possible after capture. Yellowfin up to 15 pounds were caught by trolling in local waters and sampled while fresh.

To obtain precooked samples for the evaluation of color, frozen fish were thawed in tanks at Hawaiian Tuna Packers, Ltd., and cut into loins. One loin from each fish was retained as a raw sample. The remaining loins were put through the regular commercial precooking process of that company. Color grade of the precooked samples was judged by the company's food technologist. Specific samples characteristic of their types (normal, green, pink, etc.) as subjectively judged, were used in much of the work.

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(400 to 700 mμ) were obtained with a Beckman DU spectrophotometer equipped with a standard reflectance attachment. All chemicals used were reagent grade.

The meat was forced through a 16-mesh stainless steel screen and packed it into a $1^1/_4 \times {}^1/_{16}$ inch aluminum planchet. Chemical treatment was accomplished by adding the reagents to the meat in the planchet. A glass plate was then pressed firmly upon the meat until a uniformly smooth surface was produced, to obtain a diffuse surface and eliminate gloss or directional color. Immediately after preparation the planchet was introduced into the reflectance attachment of the spectrophotometer, and relative reflectance was measured by comparison with a pure high-fired alumina disk, likewise covered with a glass plate. Apart from oxidative variations, well ground and thoroughly homogenized samples gave readings that were reproducible to ±0.5% reflectance unit. Replicate, nonhomogenized samples from the same fish loin gave an average precision of ±1.5% reflectance unit. Absorbance (optical density) was used in the curve plots, because Beer's law was obeyed in the systems studied.

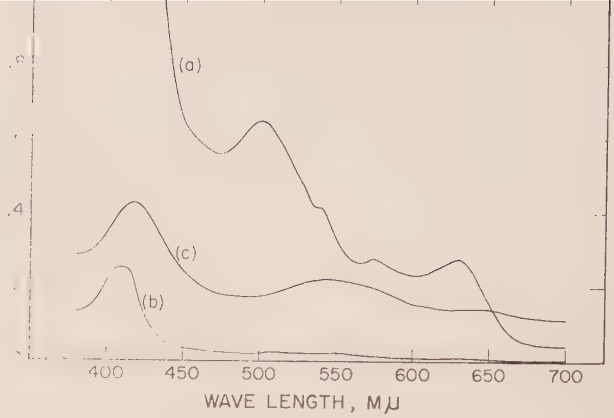

Figure 1. Separation of aqueous extract of raw tuna into methemoglobin and metmyoglobin by phosphate fractionation

a. Transmission curve for original extract
b. Transmission curve for residual solution after methemoglobin precipitation with phosphate
c. Reflectance curve of phosphate precipitated material

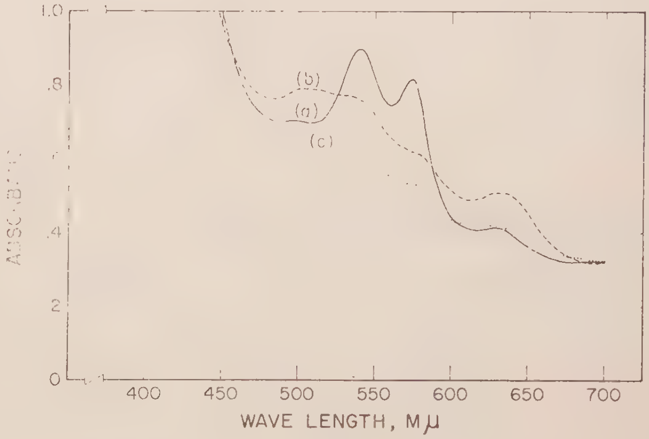

Figure 2. Reflectance curves showing pigment mixture found in raw tuna flesh

a. Largely oxyhemoglobin
b. Largely methemoglobin
c. Mixture of met- and oxyhemoglobin

SOME CHARACTERISTICS OF THE PIGMENTS

Nature of Pigments in Raw Tuna Meat A natural assumption is that myoglobin, or muscle hemoglobin, is a major pigment imparting color to the tuna flesh. Certain experiments have cast doubt on the validity of this assump- Bowen (*2*) and others have found absorption peaks for mammalian myoglobin are displaced to longer wave lengths in the case of certain derivatives of the pigment. The peaks for the corresponding derivatives of tuna pigments were carefully measured and no such shift was observed. Instead, the curves obtained were identical with those characteristic of hemoglobin and its derivatives. To substantiate these results, the solubility of the extracted pigments in buffered phosphate was checked according to the procedure of Morgan (*17*) as modified by Ginger, Wilson, and Schweigert (*10*). The separation of the myoglobin from the hemoglobin by this method is based upon the solubility of the former and the insolubility of the latter compound in the phosphate buffer. The myoglobin was estimated as metmyoglobin through transmission measurements and the hemoglobin as methemoglobin by the examination of the residue through spectral reflectance.

Assuming that these procedures separate myoglobin from hemoglobin on the basis of their solubility in the differentiating medium, it was found that the pigments in tuna flesh were about 95% hemoglobin, with myoglobin comprising a minor fraction of the pigment system (Figure 1). Matsuura and Hashimoto (*14*) report all pigment in ordinary muscle of yellowfin tuna as hemoglobin (140 mg.%). The experiments described have not been sufficiently exhaustive to warrant a definite conclusion regarding this point. The main muscle pigment in tuna meat, if not hemoglobin, may be different from the corresponding pigment in mammalian flesh (*20*). Thus, the actual nature of the pigment in tuna meat is not yet definitely established. The distribution of the pigments, however, between myoglobin and hemoglobin is not pertinent to the color changes in tuna meat, because these involve the porphyrin moiety which is identical for both. The pigments in tuna flesh are referred to hereafter as hemoglobin or its derivatives.

Examination of the raw tuna meat by means of spectral reflectance seemed to indicate that oxy- and methemoglobin were the principal heme pigments present. Some typical curves characteristic of the oxy- and methemoglobin mixtures encountered are shown in Figure 2.

Pigment Changes in Raw Flesh **Conversion of Oxyhemoglobin.** Fairly rapid oxidative deterioration was observed in tuna meat even when stored in a freezer. The concomitant conversion of oxyhemoglobin with time was observed by following the change in the reflectance spectra periodically (Figure 3). Complete conversion to methemoglobin was accomplished quickly by oxidation with potassium ferricyanide (Figure 3,*B*,*e*). That the changes correspond to a decrease in oxyhemoglobin can be verified by comparison of these data, presented as simplified curves, with similar changes in absorption obtained by Austin and Drabkin (*1*) for oxy- and methemoglobin mixtures of known composition (Figure 3,*A*).

Examination of these results indicated that the pigment systems in tuna meat were extremely susceptible to environmental changes. The major change that takes place at freezer temperatures is a conversion of oxyhemoglobin to methemoglobin which is not desirable, because it is accompanied by a certain degree of discoloration. This, in turn, might decrease the value of the meat from the commercial standpoint.

Deoxygenation of Oxyhemoglobin. An attempt at reducing oxyhemoglobin to hemoglobin by exposing the tuna meat to evacuation and a purified nitrogen purge, a procedure which normally removes the oxygen of the oxy-compound, resulted in a rapid conversion of oxyhemoglobin to methemoglobin. Typical reflectance spectra showing this change are presented in Figure 4. The results may be an example of the phenomenon noted by Brooks (*3*), who found that the conversion of oxyhemoglobin to methemoglobin proceeded more gen, with a maximum at 20 mm.

Pigment Denaturation. Examination of the spectral reflectance curves of raw tuna meat reveals that some degree of denaturation of the protein moiety of the heme pigment molecule takes place even at low temperatures. Such denaturation produces denatured globin hemichromes (*12*) more easily identified in the reduced condition as the denatured globin hemochromes, because their absorption curves exhibit pronounced peaks at 528 and 558 mμ. Figure 5 shows representative spectral curves obtained with tuna meat. Fresh tuna meat, chemically reduced with dithionite, gives the characteristic absorption peak of hemoglobin at 555 mμ (Figure 5, *a*). When subjected to mild denaturation by heating to 50° C. for 20 minutes the same reduced meat exhibits the distinct hemochrome peak at 528 mμ (Figure 5,*b*). Similar denaturation can be observed in curve *c* for a reduced raw sample which is rich in methemoglobin and in curve *d* for a second sample of the same type of meat commercially precooked and reduced. It is remarkable that precooking, as in the last instance, does not appear to have increased the denaturation of the pigment markedly as judged by the hemochrome peak at 528 mμ. There is some indication from a number of such raw, reduced samples that the degree of denaturation in tuna meat is directly related to the amount of methemoglobin originally present.

Solubility of Methemoglobin. The unexpectedly greater solubility of methemoglobin in aqueous media when compared to oxyhemoglobin in tuna meat is an example of unusual pigment changes and behavior encountered in this research. Aqueous extracts of tuna flesh gave absorption curves characteristic of methemoglobin. Examination of the reflection spectra of tuna meat obtained before and after subjecting samples to leaching action showed that methemoglobin is characterized by a rather great solubility in water, whereas oxyhemoglobin exhibits a high degree of insolubility. A typical case demonstrating this difference is shown in Figure 6. This suggests that pigment leaching during thawing and precooking might be a factor in producing a washed-out condition in tuna and in other meats with a high methemoglobin content. It might also be applied as a means of lightening meat color, and of removing flesh pigments that might be decolorized during precooking.

Pigments in Cooked Tuna Meat

Cooking of tuna meat results in the denaturation and coagulation of the proteins present with concomitant lightening of the meat color. Denaturation of the heme proteins leads to the formation of the hemochrome of the denatured globin. Characterizing absorption, aside from the Soret region, occurs at 545 and 575 mμ (Figure 7, curves *a* and *b*), in agreement with the values listed for the denatured hemochrome of hemoglobin (*12*). Because the absorption of this substance is weak and poorly defined, the more easily characterized curve of the reduced, or ferrous, denatured globin hemochrome previously mentioned was used for identification purposes. The contrast is evident in the examples given in Figure 7. The color of the reduced hemochrome is the normal pink which is considered commercially desirable.

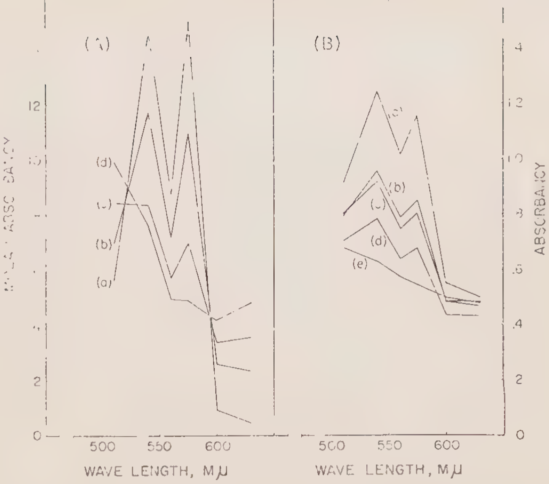

Figure 3. Absorption curves

A. Simplified curve shows decreasing concentration of oxyhemoglobin, in mixture with methemoglobin decreasing from *a* to *d* (*1*)
B. Similar simplified curve taken in reflection for tuna meat after various periods of freezer storage, showing decreasing oxyhemoglobin content

a. Fresh tuna meat
b. After 24 hours of freezer storage
c. After 36 hours of freezer storage
d. After 84 hours of freezer storage
e. After complete conversion to methemoglobin by oxidation with potassium ferricyanide

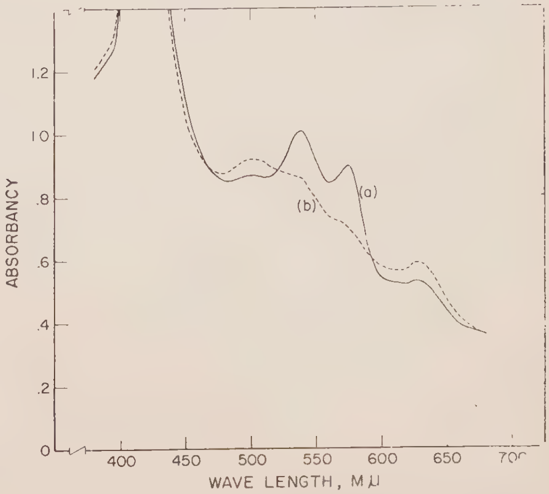

Figure 4. Oxidation of flesh pigment on treatment with nitrogen

a. Reflectance curve of fresh tuna meat
b. Reflectance curve after alternating evacuation and treatment with nitrogen for 3 hours

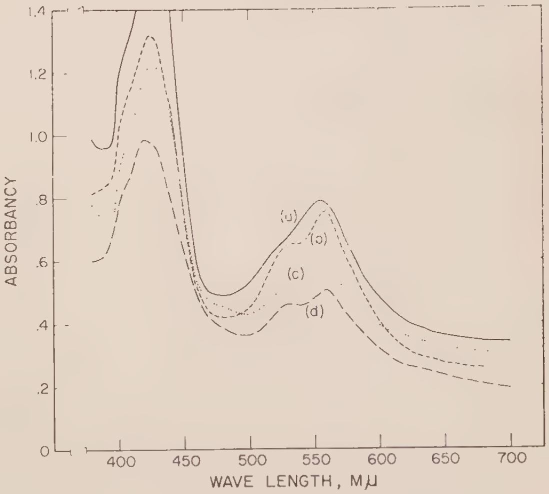

Figure 5. Reflectance curves showing denaturation by appearance of hemochrome band at 528 mμ after reduction with dithionite

a. Reduced raw fresh tuna hemoglobin
b. Tuna flesh of curve *a* after denaturation by heating 20 minutes at 50° C.
c. Reduced raw methemoglobin rich sample
d. Methemoglobin rich sample, commercially precooked, and reduced

DISCOLORATION OF TUNA MEAT

Color of Precooked Tuna Meat. Visual examination of different samples of cooked tuna meat reveals the complexity of the color system involved. Variations from highly bleached to abnormally red meat have been encountered which demonstrate the fluctuations of the absolute content of pigment in the flesh of different fish. It has not been determined whether these variations are physiological or post-mortem in nature. A brown condition is recognized dation of the natural hemochrome on exposure to atmospheric oxygen (*4*). The greening phenomenon, the main object of this research, and an orange coloration are also frequently observed. Both discolorations permeate the fish flesh rather than being associated with exposed surfaces as in the brown condition. The distribution of pigment within a single fish loin, seemingly uniform to the eye, was variable. This was confirmed by a superficial microscopic examination which showed the pigment to be present in bands within the metal. Spectral reflectance measurements gave variable estimates of the amount of pigment present. Uniformity could be assured only by grinding and thoroughly mixing all the meat required in a given sample sequence. This was not usually done because finely ground meat changed color even when held in a frozen condition.

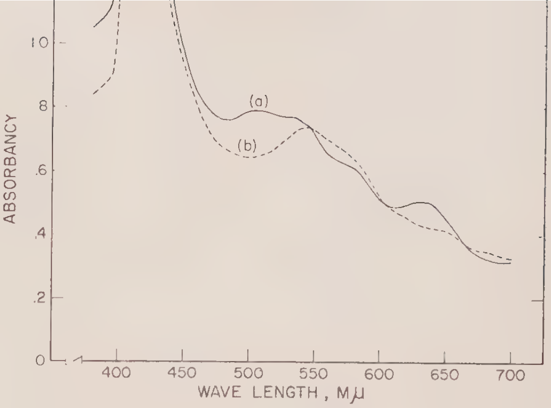

Figure 6. Reflectance curves showing solubility of methemoglobin and insolubility of oxyhemoglobin in raw tuna flesh

a. Raw tuna flesh
b. Residual flesh after aqueous extraction at pH 6.8. Note disappearance of 500 and 630 mμ methemoglobin absorption peaks

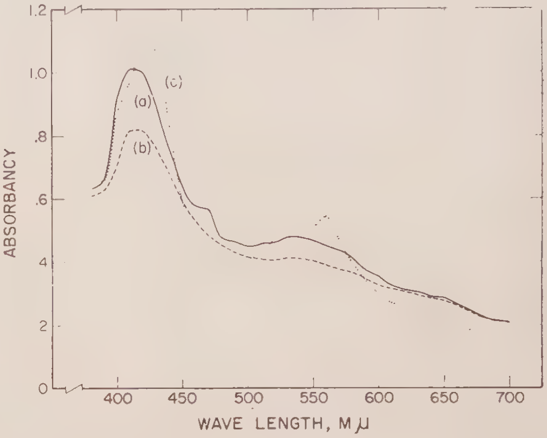

Figure 7. Reflectance curves showing pigments of cooked tuna flesh

a, b. Denatured globin hemochrome of cooked tuna flesh
c. Denatured globin hemochrome of reduced, cooked tuna flesh

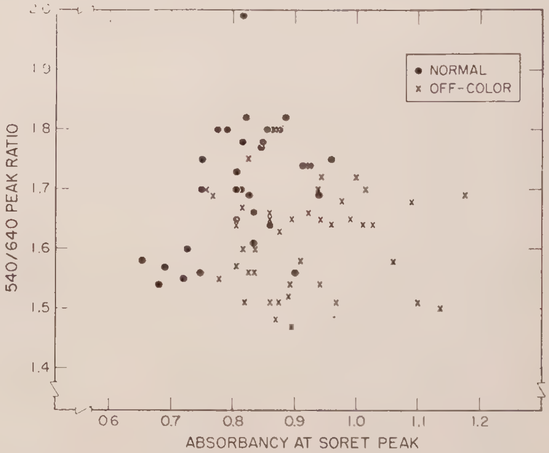

Figure 8. Variation of 540/640-mμ peak ratio with absorbancy at Soret peak (410–415 mμ) an index of pigment content

A method used to evaluate greenness objectively was to compare absorption in the red and green parts of the spectrum (640 and 540 mμ, respectively) for cooked, green, and normal meat by reflectance. A green sample would be expected to show greater absorption of light in the red end of the spectrum than in the green, when compared with normal meat. The ratio of the absorbancies at the 540/640-mμ absorption peaks should be greatest for normal and least for green meat. Absorbancy ratios have been used by other investigators (*6*) in evaluating, objectively, the color of cured meats.

It became evident that pigment content was a factor affecting the degree or type of alteration that might occur. Upon the assumption that the height of the most characteristic absorption peak for heme pigments (the Soret peak, at about 415 mμ) can be used as an indication of the absolute pigment content of the cooked meat, several significant relationships were observed by plotting this peak against the above indicated greenness index (540/640 absorption peak ratio) (Figure 8). Normal samples, in general, occupy the portion of the figure indicative of higher 540/640 peak ratio as would be expected, and lower pigment content. It is noteworthy that both the albacore white color resulting from low pigment content and the fleshy pink color associated with a high 540/640 peak ratio are accepted as normal by observers, thus emphasizing the complexity of the systems encompassed by the term normal. The overlapping position of some of the points is due, at least in part, to the uncertainty and ambiguity inherent in the subjective evaluation of precooked flesh.

Green Pigmentation in Precooked Tuna Flesh. It was impractical to extract and identify the green component in precooked green flesh by the use of simple solvent systems. Attempts were made to cleave the pyrrole ring segment from the protein moiety of the pigment molecule by alcohol– or acetone–hydrochloric acid treatment, and to examine the extract by spectral transmission, and the residue by spectral reflection. Green pigmentation in meat has been attributed to an oxidative attack on the pyrrole ring of the heme pigments producing choleglobin or verdohemochrome (*24*). Removal of the oxidized or disrupted ring by the acid-alcohol or acetone treatment, and spectral examination should reveal the nature of the parent pigment. Verdohemochrome, and its postulated precursor choleglobin, for example, would produce biliverdin-like compounds (*12*).

The acid alcohol extracts gave an absorption curve in transmission which showed no characteristic absorption peaks and was very similar to that obtained from the aqueous residue left on cooking the fish (Figure 9, *b*). Extraction of this material with chloroform, however, gave in the extract an absorption curve with transmission peaks at 382, 510, 540, and 640 mμ (Figure 9, curves *a* and *c*). These absorption maxima are compared in Table I with the peaks reported for some of the products of heme protein disruption.

The coincidence of the absorption peaks with those reported by Lewis (*13*) for hemin chloride in acetone with excess hydrochloric acid added is striking. It indicates that this substance may be present in the extract. Microscopic examination of the evaporated residue of these extracts failed to reveal the characteristic hemin chloride platelets. No evidence of oxidative disruption of the pyrrole ring was obtained in the soluble fraction from acid-acetone or acid-alcohol treatment.

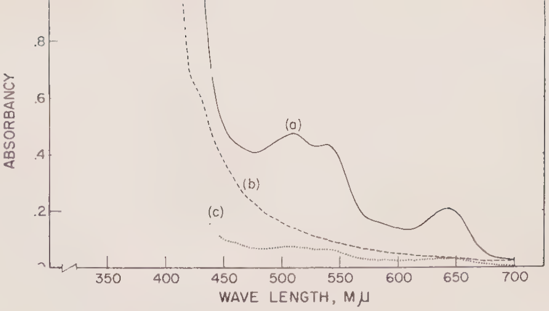

Figure 9. Spectral absorbance measured in transmission of extracts of precooked green tuna flesh

a. Chloroform extract of hydrochloric acid–acetone extract
b. Original hydrochloric acid–methanol extract
c. Chloroform extract of b

Table I. Characteristic Absorption Peaks of Heme Pigment Derivatives

Pigment	*Absorption Maxima, Mμ*			
	I	*II*	*III*	*IV*
Muscle pigment in chloroform	640	540	510	382
Hemin chloride and hydrochloric acid (*13*)	640	540	512	382
Green skeletal pigment of skipjack in chloroform (*7*)	660	. .	. .	380
Methanolic ester of biliverdin in chloroform (*23*)	685	. .	. .	380
Biliverdin hydrochloride in hydrochloric acid–methanol (*12*)	680	. .	. .	377
Protoporphyrin in ether–acetic acid (*12*)	632.5	537	502	395
Coproporphyrin in chloroform (*11*)	622.5	533	499	405

flesh with acid-acetone and acid-methanol were examined by spectral reflectance. The main characteristics of the curves obtained were very similar to those reported for acid hematin and acid-stable hemin (*13*).

Of interest was the slight, but definite absorption peak in the red end of the spectrum at 625 mμ for acid-acetone–treated meat (Figure 10, *a*, *b*, and *c*). The curves show a decrease in this peak height from very green meat (curve *a*) to less green (curve *b*) to normal (curve *c*), where the absorption peak has disappeared. This peak is a more direct point of evidence for the green pigment, the existence of which had previously been deduced more or less indirectly. A similar pigment, absorbing between 610 and 620 mμ, has been reported by Ginger, Lewis, and Schweigert (*9*) in both transmission measurements on green-colored extracts and spectral reflectance curves obtained from discolored beef that had been exposed to gamma radiation from a cobalt-60 source. The pigment noted here is present in a very much lower concentration and in an insoluble coagulated form, rendering it difficult to detect in the presence of other pigments, and impossible to extract into a solvent.

A pigment present in beef, which may be similar, has been identified as being largely sulfmyoglobin (*8*).

Relationship between Pigments of Raw and Precooked Tuna Flesh. The examination of many spectral reflectance curves for the flesh of raw tuna revealed the tendency for flesh with a high content of methemoglobin, characterized by a prominent 630-mμ absorption peak, to exhibit an off-color on precooking. The picture is complicated by the presence of oxyhemoglobin, which seems to modify the effect of methemoglobin and, when present in high concentration, produces pink meat that browns rapidly on exposure to air. Frequently a high concentration of both oxyhemoglobin and methemoglobin is found. The possible combinations result in a gamut of gray to brown to orange pigmentation on precooking, depending on the relative amounts of each parent pigment.

An evaluation of the relationship of both subjectively and objectively judged color to methemoglobin content is shown in Figures 11 and 12. The height of the absorption peak in the red region at 630 mμ, characteristic of methemoglobin, was used as an indication of the amount of this pigment in the raw meat and was measured by means of the ratio of 630/660-mμ absorption. Off-color of the same meat on precooking was judged subjectively by the food technologist of Hawaiian Tuna Packers on a scale which included: plus one (excellent), zero (normal), and minus value (for increasing degrees of greenness and off-color) (Figure 11). There seems to be a definite relationship between these factors.

Objective evaluation of greenness in precooked meat was made through the use of the absorption ratio at 540/640 mμ. The comparison of this color rating with the methemoglobin content is shown in Figure 12. An interrelationship is indicated, complicated by the orange color abnormality that is frequently encountered. It is surprising that this also seems to be related to a high methemoglobin content. The large number of coexisting flesh pigment forms and colors (pink, orange, green, and brown) gives a complicated system in which correlating factors are readily obscured. Nonetheless, the evidence seems to point rather definitely to methemoglobin as a dominating factor in the discoloration of tuna flesh.

Relationship of Fat Peroxides to Discoloration. The suspicion of oxidation, as one factor related to greening, has led to speculation on the role of fat peroxides in this phenomenon. The coupled oxidation of hemoglobin and unsaturated fats in mammalian meat tissue has been the subject of much research (*24*). The oxidation of unsaturated fats to peroxides is accelerated by heme compounds and is accompanied by the oxidation of the heme. The resulting fat peroxide may, in turn, play a role in furthering the deterioration of heme pigments. Hydrogen peroxide forms unstable addition compounds with hemoglobin, which subsequently decompose with destruction of the heme moiety of the molecule (*11*). A greening of tuna meat has been observed on treatment with dilute solutions of hydrogen peroxide.

To test the possibility of a correlation between peroxide formation and oxidation of the heme pigment, the fat content of tuna flesh has been determined by a modification of the cold extraction method of Sperry (*22*), carried out in deaerated solutions under a blanket of nitrogen. The peroxide content was determined by titration of iodine with standard thiosulfate solution (Table II). The iodine was released from an iodide solution by the peroxide present in the extracted fat. Appropriate blank determinations were made.

For the samples run, there is an indication of a high peroxide content in green and off-color flesh, which is in agreement with the postulated oxidation of fats along with the oxidation causing greening. The increased peroxide is most pronounced for abnormally pink or orange samples, and less so for green.

The investigation of the fat content and the peroxide values, related as they seem to be to the oxidation of heme compounds, is particularly pertinent, because it is known that fish derive their fat mainly, if not entirely, from dietary fat. The fat is deposited in the tissues more or less unchanged (*21*). The highly speculative conjecture could be made that the differences among fish of the same species, which result in greenness being exhibited by certain specimens, are related to differences in dietary fat intake. The presence of fats susceptible to oxidation—i.e., linoleic and linolenic acid fats—would in turn render the heme pigments present subject to easy oxidation.

Fish Exhaustion and Methemoglobin Content. As a result of the accelerated conversion of oxyhemoglobin to methemoglobin in the absence of oxygen (nitrogen and evacuation), anoxia, or lack of oxygen, in the muscle of the fish brought on by exhaustion might lead to a high methemoglobin content with consequent increased incidence of greening. Such a condition is probable for certain

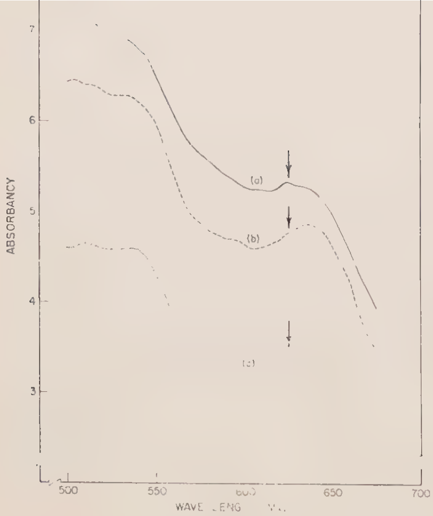

Figure 10. Reflectance curves of acid-acetone – extracted precooked tuna of decreasing greenness

a, b, c. Absorption decrease with decrease in greenness in the 610–620-mμ range

Samples	Description	Fat, %	Meq. Peroxide/1000 Grams Fat
Green			
1	Green	1.29	40
2	Pale green	0.47	14
3	Slightly green	0.63	24
4	Green	0.82	14
		0.79	12
Very pink			
1	Abnormally pink	0.55	27
2	Abnormally pink	0.92	20
		1.07	40
3	Orange	0.46	26
		0.44	22
Normal and Pale			
1	Normal	0.50	13
2	Washed out	1.57	9
3	Normal	0.59	9
4	Normal	0.58	4
5	Normal	0.54	10
		0.51	8

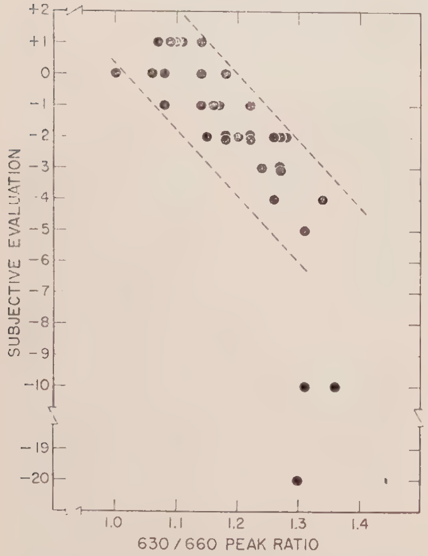

Figure 11. Relationship of methemoglobin content of raw tuna flesh to color rating as subjectively judged

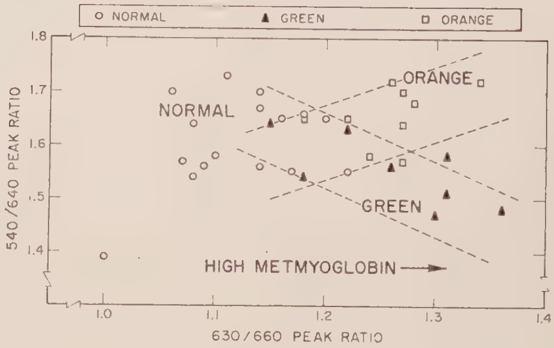

Figure 12. Relationship of methemoglobin content of raw fish flesh to color of meat after precooking as objectively judged (540/640 ratio)

Measurements made from absorption in spectral reflectance

fish caught by the long-line method of fishing.

The theory was tested through the facilities of the Coconut Island Marine Laboratory of the University of Hawaii. A fishing boat was available with a live-well in which it was possible to maintain small tuna alive. In addition, small yellowfin tuna abound in local waters in certain seasons. With the cooperation of the staff of the Hawaii Marine Laboratory, it was possible to catch tuna with lures and to kill certain of these within a few minutes of capture while maintaining others in a wounded and dying condition for many hours in the live well. The latter were finally killed and the flesh of both types was analyzed for methemoglobin by the reflectance technique. Two sets of such paired samples were obtained. Differences in methemoglobin content were very slight and seemed to be randomly distributed between the fish killed under the two conditions.

Acknowledgment

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DISTRIBUTION, ABUNDANCE, AND HABITS OF PELAGIC SHARKS IN THE CENTRAL PACIFIC OCEAN

BY DONALD W. STRASBURG

FISHERY BULLETIN 138
From Fishery Bulletin of the Fish and Wildlife Service
VOLUME 58

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

UNITED STATES DEPARTMENT OF THE INTERIOR, Fred A. Seaton, *Secretary*
FISH AND WILDLIFE SERVICE, Arnie J. Suomela, *Commissioner*

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BY DONALD W. STRASBURG

March 3, 1849

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ABSTRACT

The distribution and abundance of the central Pacific pelagic sharks was investigated by longline fishing methods during 1952–55. In this period more than 6,000 sharks were caught; these belonged to 12 species. Great blue, whitetip, and silky sharks predominated. Bonito, thresher, mackerel, and other species were uncommon or rare.

Several significant facets of the biology of the common sharks were evident. The wide-ranging great blue shark made pronounced seasonal migrations during which sexual segregation occurred and reproduction probably took place. Vertical distribution of the great blue shark was limited in the north by the 45°–69° F. isotherms, and it was truly an oceanic species. The whitetip and silky sharks were denizens of the Tropics, and showed no particular migratory tendencies; the former was oceanic but the latter tended to be neritic.

In equatorial waters, great blues and whitetips were more abundant in warm years, and the silky more abundant in cold years. The species considered here fed principally on small fish and squid. The great blue shark was virtually harmless to the tuna catch. Only 1 percent of the catch was damaged where it abounded, as compared with 20 percent damaged in regions where the whitetip and silky sharks were dominant. In the great blue shark both the behavioral and geographical types of sexual segregation were found, and sexual segregation itself was related to latitude, shark length, and season.

DISTRIBUTION, ABUNDANCE, AND HABITS OF PELAGIC SHARKS IN THE CENTRAL PACIFIC OCEAN

By **Donald W. Strasburg**, *Fishery Research Biologist*, BUREAU OF COMMERCIAL FISHERIES

The Pacific Oceanic Fishery Investigations (POFI) of the United States Fish and Wildlife Service is authorized to investigate the high seas fishery resources of the tropical and subtropical Pacific Ocean. A large part of POFI's research program has dealt with the biology of tunas, the stocks of which have been sampled extensively by longline fishing. In addition to tuna, spearfish, and other species of commercial importance, an incidental product of longlining has been the capture of numerous pelagic sharks. Information on the occurrence of these sharks is of importance to both the biologist and the commercial fisherman because of the sharks' competitive and predatory relation to tuna and also because of the damage sharks inflict on hooked tuna. Apart from discussions in systematic and general works (Bigelow and Schroeder, 1948, Englehardt 1913, Norman 1949, and Norman and Fraser, 1949) and the usually fragmentary data in faunal reports, little is known of the biology of high seas sharks, and any information on their abundance, distribution, and habits is of practical and academic interest.

This report is primarily based on the shark catches recorded during the years 1952 through 1955. During this period the POFI ships *John R. Manning*, *Charles H. Gilbert*, and *Hugh M. Smith* conducted 26 longline cruises, which obtained sharks in the central Pacific between 50° N. and 20° S. latitude, and 110° W., and 175° E. longitude (fig. 1). During the same period of years, four privately owned, commercial vessels, the *Cavalieri*, *Commonwealth*, *North American*, and *Oceanic*, operating in conjunction with POFI, made a total of eight cruises to the Line Islands area. Data from all the above cruises were utilized only when the shark catches were recorded by species. Although a considerable portion of these data have routinely been listed in reports by workers concerned primarily with tuna (Murphy and Shomura, 1953a, 1953b, 1955; Shomura and Murphy, 1955; Shomura and Otsu, 1956; Iversen and Yoshida, 1956), it seems advisable to provide a summary of the catch and effort for the various cruises (table 1).

METHODS

The longline gear used by POFI as a tool for sampling the abundance of tunas (and sharks) has been described by Niska (1953) and Mann (1955). A unit or basket of longline gear consists of 210 fathoms of mainline supporting a number of hook droppers, usually 3 fathoms in length, and buoyed at its end by floats attached to 5-, 10-, or 15-fathom floatlines. Numerous baskets are joined together to form a set, each basket being placed in the water in a slack condition so that the 210-fathom mainline sags and subtends a distance of only about 150 fathoms between floats. The number of droppers per basket was typically 6, 11, or 13, although experimental gear employing 14, 15, and 21 droppers was occasionally used during the period under consideration. Bait consisted of frozen herring, sardines, or squid. Setting of longlines usually started at dawn and required about an hour. Recovery commenced at noon and was usually completed in 4½ hours. The last basket set was the first one retrieved.

In their classic treatise on North Atlantic sharks Bigelow and Schroeder (1948) frequently refer to nomenclatorial confusion resulting in nonacceptability of shark records. This confusion has several causative factors, chief of which is the lack of large preserved specimens available for systematic study. Further complicating the situation is the existence of several sets of names for sharks, e. g., one set for Atlantic species, another

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NOTE.—Approved for publication September 5, 1957. Fishery Bulletin 138.

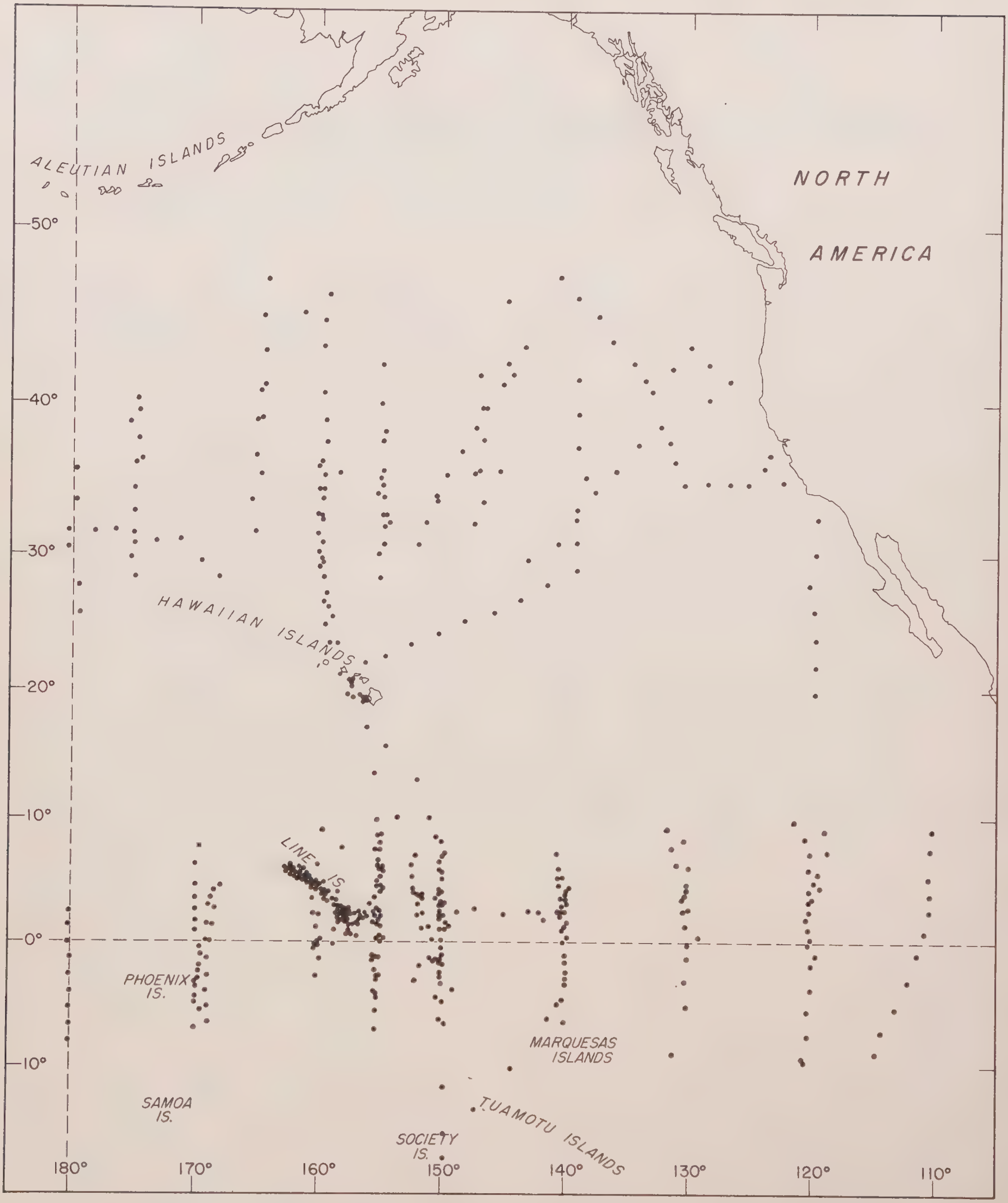

ALEUTIAN ISLANDS
NORTH AMERICA
HAWAIIAN ISLANDS
LINE IS.
PHOENIX IS.
SAMOA IS.
SOCIETY IS.
TUAMOTU ISLANDS
MARQUESAS ISLANDS
50°
40°
30°
20°
10°
0°
10°
180°
170°
160°
150°
140°
130°
120°
110°

FIGURE 1.—Location of longline stations from which the sharks reported on were obtained.

TABLE 1.—*POFI and commercial longline cruises yielding identified sharks during the period 1952–55*

Vessel	Cruise	General operational area [1]	Date	Number of stations	Total hooks	Shark catch			
						Great blue	White-tip	Silky	Other
John R. Manning	11	Equator at 159° W., 169° W., 180°.	January–March 1952	27	6, 960	51	71	31	1
	12	Equator at 140° W., 150° W	August–September 1952	18	4, 560	13	59	5	8
	13	Equator at 150° W., 169° W	October–November 1952	27	7, 620	20	131	19	0
	14	Equator at 140° W., 150° W	January–March 1953	33	8, 850	25	140	25	3
	15	Equator at 150° W., 170° W	April–June 1953	28	9, 521	47	109	42	9
	16	Equator at 155° W., 160° W	July–August 1953	26	8, 811	47	47	139	5
	17	Line Islands	October–November 1953	6	2, 418	2	2	48	1
	18	Equator at 155° W., Line Islands.	December 1953	14	7, 140	15	76	92	5
	19	22° N.–36° N., 145°.–160° W.	January–March 1954	18	14, 014	91	3	0	11
	20	Line Islands	May–June 1954	27	15, 764	32	108	268	3
	21	Hawaiian Islands	July 1954	5	2, 052	7	4	0	0
	22	22° N.–47° N., 159° W.–177° W	September–October 1954	16	11, 869	170	1	0	6
	23	22° N.–37° N., 157° W.–180°	December 1954–February 1955.	18	13, 415	131	0	0	4
	24	Line Islands	March–April 1955	10	6, 422	15	32	79	7
	25	28° N.–41° N., 158° W.–175° W	May–June 1955	18	8, 318	229	0	0	23
	26	30° N.–47° N., 122° W.–152° W	July–September 1955	38	19, 609	719	0	0	16
	27	Line Islands	October 1955	11	6, 928	11	9	121	9
	28	do	November–December 1955	5	3, 955	7	25	35	0
Charles H. Gilbert	1	Equator at 120° W., 130° W	May–June 1952	14	3, 360	16	32	16	0
	10	Hawaiian Islands	March 1953	3	623	4	2	0	0
	15	South of Baja California, and Equator at 110° W., 155° W.	February–April 1954	32	15, 271	323	31	51	8
	20	Line Islands	March–April 1955	14	9, 054	43	14	130	9
	23	36° N.–47° N., 145° W.–165° W	September–October 1955	8	4, 147	54	0	0	1
Hugh M. Smith	18	Equator at 120° W., 130° W	October–November 1952	23	5, 520	59	83	28	2
	19	Line Islands	January–February 1953	8	2, 160	6	3	68	1
	29	22° N.–42° N., 139° W.–156° W	May–June 1955	30	15, 600	218	0	0	14
Commonwealth	1	Line Islands	July–August 1954	11	5, 500	2	28	54	3
	3	do	May 1955	11	3, 537	6	1	28	18
	4	do	July–August 1955	12	4, 095	7	1	102	5
	5	do	September–October 1955	10	4, 210	10	5	55	3
North American	1	do	January–February 1954	27	21, 283	30	19	258	31
	2	do	March–April 1954	40	35, 965	58	86	347	23
Cavalieri	1	Equator at 140° W., 150° W	August–September 1952	26	11, 454	42	65	3	8
Oceanic	1	Line Islands	June 1954	9	3, 762	2	0	132	6
Total					303, 767	2, 512	1, 187	2, 176	243

[1] The term "Equator" denotes fishing in the equatorial area, and not necessarily along 0°. The position of the Line Islands is bounded roughly by 0°–10° N. latitude and 155° W.–165° W. longitude.

for northwest Pacific species, a third for Hawaiian forms, etc., a situation comparable to that found for other pelagic fish such as the tunas, marlins, and flying fishes. For comparative purposes it is thus necessary to note the identification sources and procedures and the disposition of the material upon which this report is based.

The principal references used in making the identifications were Bigelow and Schroeder's treatise (1948), supplemented by the reports of Roedel and Ripley (1950), Roedel (1953), and Schultz et al. (1953). On early cruises sharks were brought aboard, identified, measured, and frequently photographed. Occasionally jaws, patches of skin, embryos, and entire adult specimens were preserved, and laboratory examination of this material has since confirmed the recorded field identifications with the reservations that the names "thresher" and "hammerhead" are based on 3 and 2 species, respectively. As biologists and fishermen became better acquainted with the various species fewer sharks were landed, and identification was often based on the gross aspects of the animals as they lay in the water alongside the vessel. There is thus a possibility of an occasional error in identification, particularly with *Isurus glaucus* and *Lamna ditropis*, which are rather similar in appearance. Specimens of each species considered are to be shipped to the United States National Museum to serve as a permanent record.

The vernacular names of sharks are used throughout the remainder of this study. These names and their currently accepted scientific equivalents are as follows:

Whitetip shark	*Pterolamiops longimanus* (Poey).
Blacktip shark	*Carcharhinus melanopterus* (Quoy and Gaimard).
Silky shark	*Eulamia floridanus* (Bigelow, Schroeder, and Springer).
Great blue shark	*Prionace glauca* (Linnaeus).
Soupfin shark	*Galeorhinus zyopterus* Jordan and Gilbert.
Bonito shark	*Isurus glaucus* Müller and Henle.
Mackerel shark	*Lamna ditropis* Hubbs and Follett.

Thresher shark	*Alopias pelagicus* Nakamura.
	Alopias superciliosus (Lowe).
	Alopias vulpinus (Bonnaterre).
Hammerhead shark	*Sphyrna lewini* (Griffith).
	Sphyrna zygaena (Linnaeus).

Representative length-frequency distributions of the three most common pelagic sharks are shown in figure 2; these will acquaint the reader with the size of the sharks encountered. Insofar as possible common names have been taken from the list proposed by the American Fisheries Society (1948). For those species not covered by this list, vernacular names were derived from Bigelow and Schroeder's treatise (1948). Latin names follow the latter authors except for the carcharhinid genera lacking spiracles. Here Springer's revision (1950, 1951) has been employed with the result that the former *Carcharhinus longimanus* and *C. floridanus* are now referred to *Pterolamiops* and *Eulamia* respectively. Identification of *Sphyrna lewini* was made in accordance with Fraser-Brunner's synopsis of the hammerhead sharks (1950).

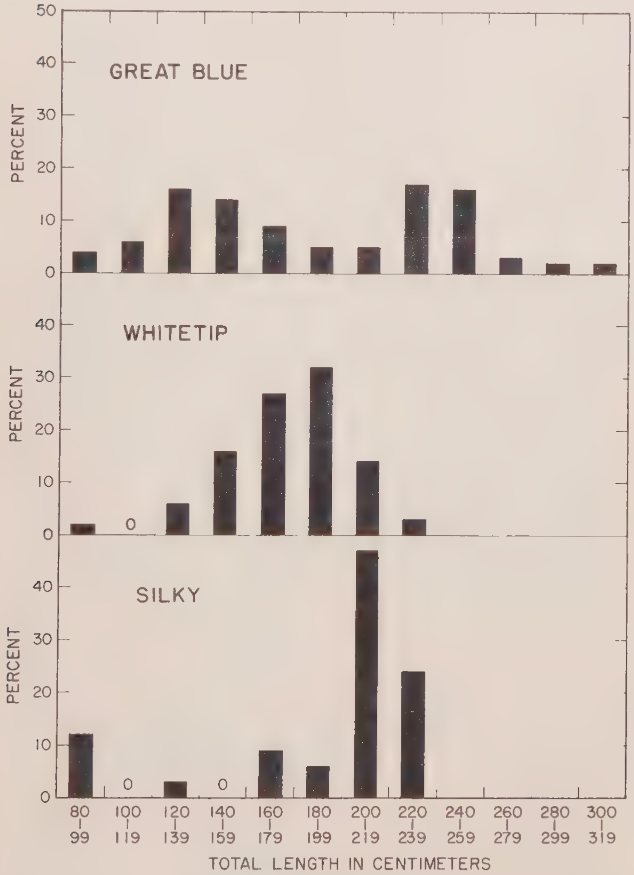


FIGURE 2.—Typical length-frequency distributions of pelagic sharks commonly occurring in longline catches in the central Pacific. Based on 106 great blue, 63 whitetip, and 34 silky sharks.

It was thought desirable to express shark abundance in terms of fishing effort, as average catch per hundred hooks per day for a certain unit of area. The operational region was accordingly divided into quadrates measuring 5 degrees on a side, and catch and effort were calculated for each areal unit. Iversen and Yoshida (1956) and Murphy and Shomura (1955) found differences in efficiency between two types of gear in catching yellowfin tuna, but all gear types were here considered equally efficient in catching sharks. It frequently happened that longline fishing stations were conducted along specified meridians or parallels, and these were also the boundaries of quadrates. Usually, the line drifted with the current so that fishing was restricted to one or the other of the quadrates, but when operations actually extended over two quadrates, the entire catch was assigned to the quadrate in which most fishing appeared to take place. This assignment took into account set and drift of the current, time spent in each quadrate, and vessel course and speed. Similarly, stations occupying parts of more than 1 day were assigned the date on which most fishing was conducted. For ease in presentation the data summarized by 5-degree quadrates have been regrouped on a 10-degree basis and are used in this form throughout most of the analyses.

The author wishes to thank all POFI scientific and vessel personnel for their efforts in landing and handling the sharks on which this report is based. Collection of shark data was begun at POFI by Dr. William F. Royce.

GENERAL RANGE AND ABUNDANCE

The distribution and abundance of the central Pacific pelagic sharks considered here are summarized in figures 3 and 4. It is apparent that high seas sharks are widely distributed as a group and that their abundance, expressed as average catch per hundred hooks per day, is usually less than that of tuna (Murphy and Shomura, 1953a, 1953b, 1955; Shomura and Murphy, 1955; Shomura and Otsu, 1956; Iversen and Yoshida, 1956). On the other hand the present data indicate a greater abundance of sharks than do those of Nomura et al. (Shomura and Murphy, 1955).

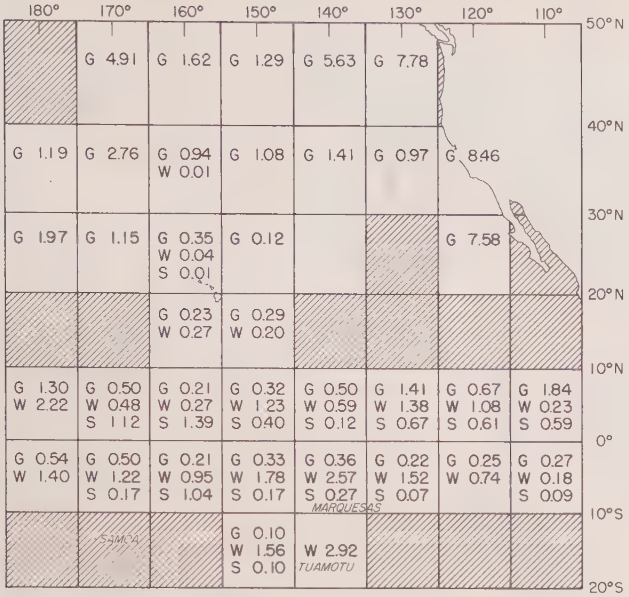

180°
170°
160°
150°
140°
130°
120°
110°
50°N
40°N
30°N
20°N
10°N
0°
10°S
20°S
G 4.91
G 1.62
G 1.29
G 5.63
G 7.78
G 1.19
G 2.76
G 0.94 W 0.01
G 1.08
G 1.41
G 0.97
G 8.46
G 1.97
G 1.15
G 0.35 W 0.04 S 0.01
G 0.12
G 7.58
G 0.23 W 0.27
G 0.29 W 0.20
G 1.30 W 2.22
G 0.50 W 0.48 S 1.12
G 0.21 W 0.27 S 1.39
G 0.32 W 1.23 S 0.40
G 0.50 W 0.59 S 0.12
G 1.41 W 1.38 S 0.67
G 0.67 W 1.08 S 0.61
G 1.84 W 0.23 S 0.59
G 0.54 W 1.40
G 0.50 W 1.22 S 0.17
G 0.21 W 0.95 S 1.04
G 0.33 W 1.78 S 0.17
G 0.36 W 2.57 S 0.27
G 0.22 W 1.52 S 0.07
G 0.25 W 0.74
G 0.27 W 0.18 S 0.09
MARQUESAS
SAMOA
G 0.10 W 1.56 S 0.10
W 2.92
TUAMOTU

Figure 3.—Distribution and abundance of three common pelagic sharks. Abundance expressed as average catch per hundred hooks per day; hatched areas not sampled. *G*=great blue, *W*=whitetip, *S*=silky shark.

Inspection of figures 3 and 4 shows that the great blue shark is wide ranging throughout the area considered whereas certain of the other species occur within rather narrowly circumscribed limits. In addition, the great blue is easily the most abundant shark in terms of POFI's longline catch, for its 2,512 records constitute about 41 percent of the entire shark catch. Its area of greatest abundance lies north of 20° N. latitude in the eastern part of the Pacific.

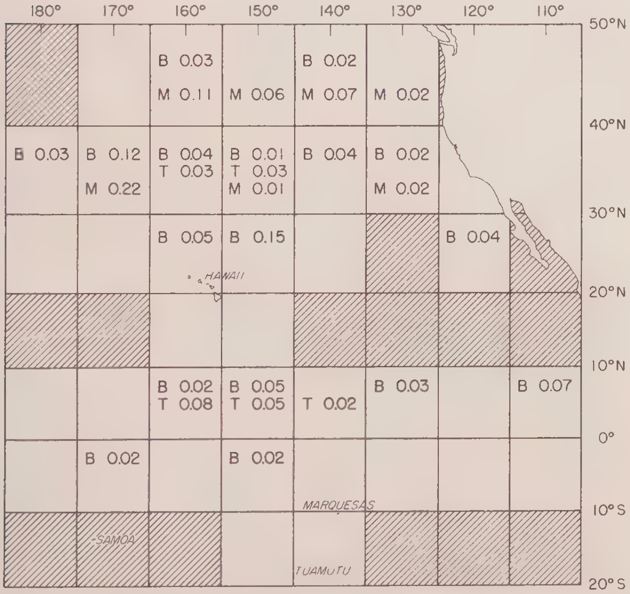

180°
170°
160°
150°
140°
130°
120°
110°
50°N
40°N
30°N
20°N
10°N
0°
10°S
20°S
B 0.03 M 0.11
M 0.06
B 0.02 M 0.07
M 0.02
B 0.03
B 0.12 M 0.22
B 0.04 T 0.03
B 0.01 T 0.03 M 0.01
B 0.04
B 0.02 M 0.02
B 0.05
B 0.15
B 0.04
HAWAII
B 0.02 T 0.08
B 0.05 T 0.05
T 0.02
B 0.03
B 0.07
B 0.02
B 0.02
MARQUESAS
SAMOA
TUAMUTU

Figure 4.—Distribution and abundance of three uncommon pelagic sharks. Abundance expressed as average catch per hundred hooks per day; hatched areas not sampled. *B*=bonito, *T*=thresher (3 species), *M*=mackerel shark.

The bonito shark has almost the same range as the great blue shark (fig. 4), but as only 74 of the former were taken the catch was almost negligible when reduced to an effort basis. The present data indicate no centers of abundance for the bonito shark although Bigelow and Schroeder (1948: 129–130) list its Atlantic counterpart as a tropical and warm-temperate species which is particularly common in the Canary and Bahamas Islands (between 20° N. and 30° N. latitude).

The silky and whitetip sharks are equatorial species, the range of the former being practically restricted to a band about 10 degrees (600 miles) on either side of the Equator, whereas that of the latter is bounded roughly by 20° N. and 20° S. latitude (fig. 3). The total catch south of 10° N. latitude consisted of 4,157 sharks of which 2,175 (52 percent) were silkies and 1,173 (28 percent) were whitetips. Despite the fact that the catch contained nearly twice as many silkies as whitetips, in terms of catch-per-hundred-hooks in the open ocean areas the whitetip is actually the more abundant of the two species (fig. 3), thus confirming Hubbs' (1951) observation that it is common in the equatorial Pacific. As implied by Bullis (1955) and pointed out by Mather and Day (1954) and Backus et al. (1956), the whitetip rather than the great blue is probably the most abundant warm-water pelagic shark.

It is of interest that the silky shark was not reported from the Pacific until the tentative identification in 1953 (Murphy and Shomura, 1953b), and its presence there was confirmed in 1956 (Iversen and Yoshida).

The region of maximum abundance for the silky shark is centered around the Line Islands area (between 0° and 10° N. and 155° W. to 165° W.), which is also the center of abundance of equatorial yellowfin tuna (Sette 1955). Whitetip concentration is more diffuse, the species being more strictly oceanic (Bigelow and Schroeder, 1948), and not congregating near land (most longlining in the Line Islands was conducted quite close to land). It has been postulated that the whitetip's oceanic existence represents a general avoidance of reduced salinities (Bigelow and Schroeder, 1948), but Backus et al. (1956) found the whitetip occurring over a wide salinity range and alternatively suggested that land avoidance may simply be the result of unfavorable food competition with faster-moving neritic species.

The catch data for the mackerel shark consist of 28 records, 26 of which are from north of 35° N. latitude indicating that this shark is a temperate- or cold-water form (fig. 4). Not shown in figure 4 is a single record from the Line Islands which is most likely based on a misidentified bonito shark.

Little can be said of the distribution and abundance of central Pacific thresher sharks except that they are uncommon (only 127 were taken) and have a tendency to congregate near land in the equatorial region as is shown later. All three species (*Alopias pelagicus*, *A. superciliosus*, and *A. vulpinus*) were taken within about 300 miles of Christmas Island in the Line Islands group, but the identity of the boreal records shown in figure 4 could not be determined.

No distributional charts were prepared for soupfin, hammerhead, or blacktip sharks as only 8, 4, and 2 specimens, respectively, were taken. The soupfins were obtained off the coast of southern California, 1 hammerhead (*Sphyrna lewini*) came from the area bordered by 0°–5° N., 120°–125° W., another (*S. zygaena*) was from 0°–5° N., and 110°–115° W., and 2 others, identified only as "hammerheads," were obtained just east of the Line Islands. The 2 blacktips were taken near shore in the Marquesas Islands, and this species should not be regarded as oceanic (Schultz et al. 1953: 15).

VARIATIONS IN SHARK ABUNDANCE WITH LATITUDE AND SEASON

Geographical variations in abundance were examined by plotting average catch per unit of effort for 10-degree bands of latitude, and temporal variations were studied by recording the data by season. The northern seasons (spring, Mar. 21 to June 20; summer, June 21 to Sept. 20; autumn, Sept. 21 to Dec. 20; winter, Dec. 21 to Mar. 20) were used with the assumption that antipodal season-reversal would not be significant in the latitudinal distribution considered. For the uncommon species (bonito, mackerel, thresher hammerhead, soupfin, and blacktip sharks), seasonal subdivision resulted in so few records per season that very little was indicated. As a consequence this section deals with the three abundant species, the great blue, the whitetip, and the silky.

In the Pacific, heavy concentrations of great blues occur only north of about 20° N. latitude (figs. 3, 5). Since the southern limits of our sampling lay between 15° S. and 20° S. it is not possible to say whether similar concentrations also exist in the Southern Hemisphere. In the Atlantic large numbers of great blues have been reported from both high and low latitudes (Bigelow and Schroeder, 1948), and the species is particularly numerous off the west coast of South Africa at about 30° S. latitude (Smith 1950).

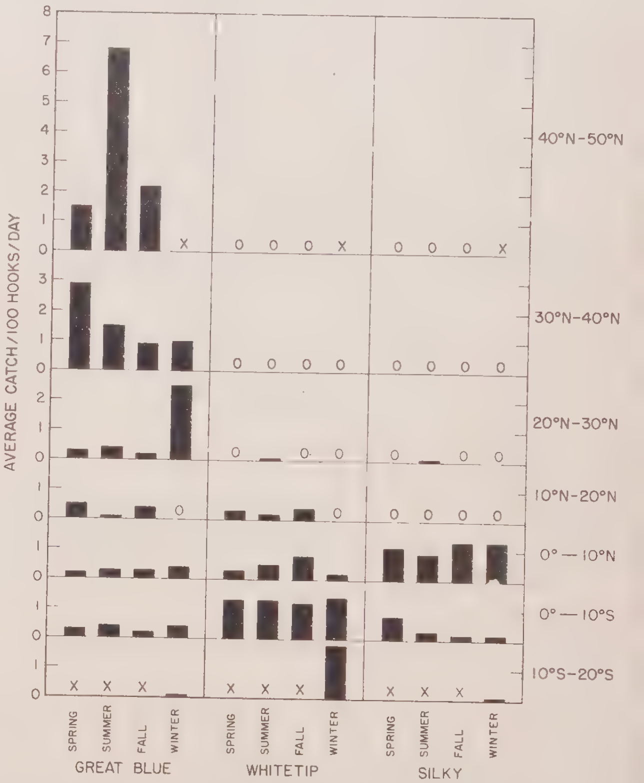


FIGURE 5.—Abundance of pelagic sharks by latitude and season. Based on 2,512 great blues, 1,187 whitetips, and 2,176 silkies. X=no fishing effort, O=no catch.

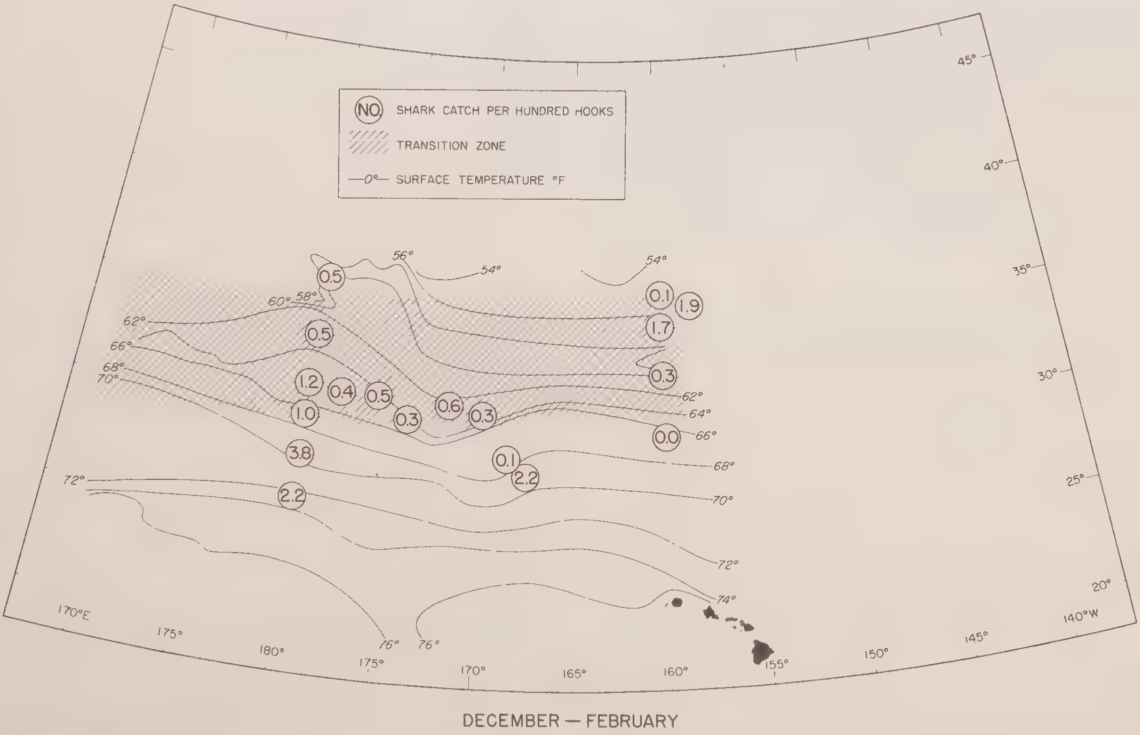
When the seasonal aspects of great blue distribution are considered (fig. 5), it appears that fluctuations are small or absent in the warm waters between 20° N. and 20° S. Between 20° N. and 30°

N. the species is most common in the winter, from 30° N. to 40° N. in the spring, and from 40° N. to 50° N. in the summer. These varying spatial and temporal concentrations indicate a north-south migration of this species, and judging from the relative constancy of its numbers in the Tropics, we deduce that temperature changes are their basis.

As pointed out by Shomura and Otsu (1956) there exists in the North Pacific a latitudinally shifting transition zone between the relatively cold Aleutian Current and the relatively warm North Pacific Current. This zone lies between latitudes 31° N. and 36° N. in the winter, and between latitudes 41° N. and 46° N. in the fall (fig. 6). Shomura and Otsu (ibid.) indicate that albacore move north and south with the advance and retreat of this zone, and the present data show that great blue sharks do also. Most of the larger catches of the great blue were made in or just south of the transition zone in water with surface temperatures ranging from 56° to 74° F., depending on the season (fig. 6). This range of surface temperatures cannot be considered as limiting their geographical occurrence because many great blues were taken from deeper, cool water in the Tropics (see p. 344).

Returning to figure 5, seasonal migrations of the great blues apparently extend only as far south as 20° N., although the absence of these sharks from the winter catch between 10° N. and 20° N. may indicate that migration also occurs there. With the onset of autumn a return southern migration presumably takes place, but this may occur outside the fishery since it is not evident from the catch data. It would seem that the number of northern migrants is augmented from populations extralimital to this study, otherwise it is difficult to explain the disparity between summer abundance at 40° N.–50° N. and spring abundance at 30° N.–40° N.

There is also the likelihood that the increase in numerical abundance in the areas to the north is the result of females giving birth to young. Large numbers of very small great blues were captured by longline in the areas during the spring, summer, and autumn. The smallest of these were about a foot and a half in total length, exactly the same size as large embryos (p. 354), and there can be little doubt that they were born shortly before capture. Unfortunately, length measurements were not routinely recorded for sharks and it is impossible to state what percentage of the popu-



DECEMBER — FEBRUARY

Figure 6a.—Relation between the great blue shark catch rate and position of transition zone, December–February. (After Shomura and Otsu, 1956.)

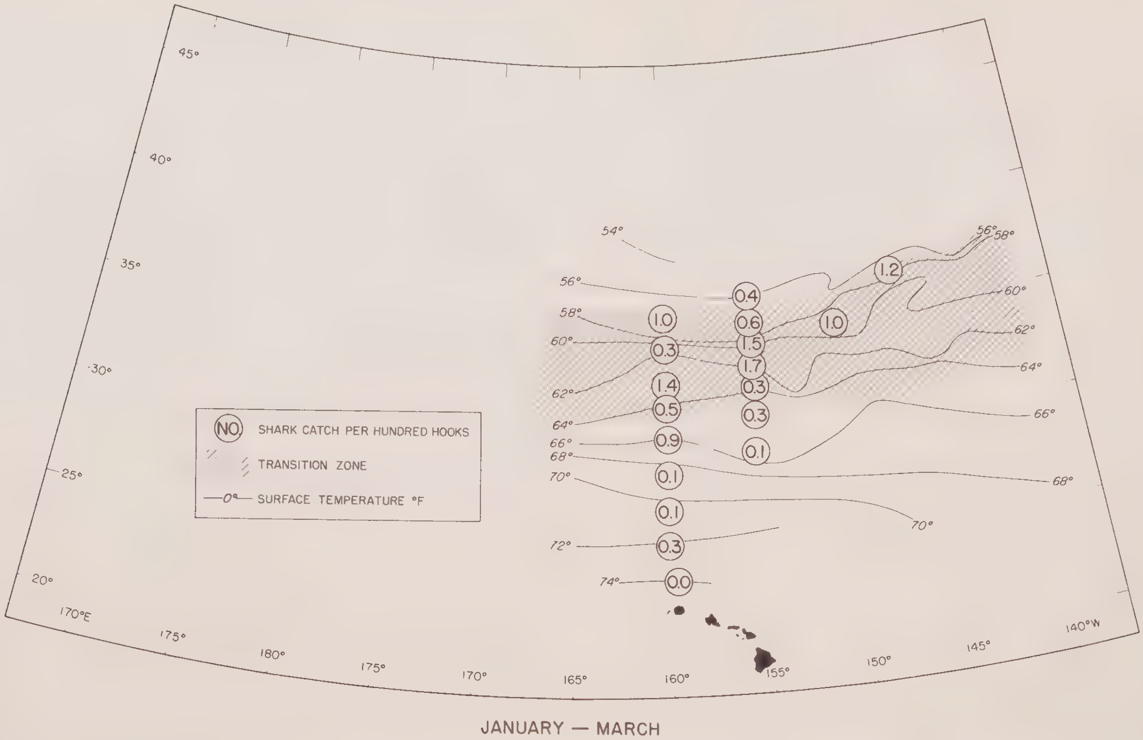

NO. SHARK CATCH PER HUNDRED HOOKS
TRANSITION ZONE
—0°— SURFACE TEMPERATURE °F
1.2
0.4
1.0
0.6
1.0
0.3
1.5
1.7
0.3
1.4
0.5
0.3
0.9
0.1
0.1
0.1
0.3
0.0
45°
40°
35°
30°
25°
20°
170°E
175°
180°
175°
170°
165°
160°
155°
150°
145°
140°W
JANUARY — MARCH

FIGURE 6b.—Relation between the great blue shark catch rate and position of transition zone, January–March. (After Shomura and Otsu, 1956.)

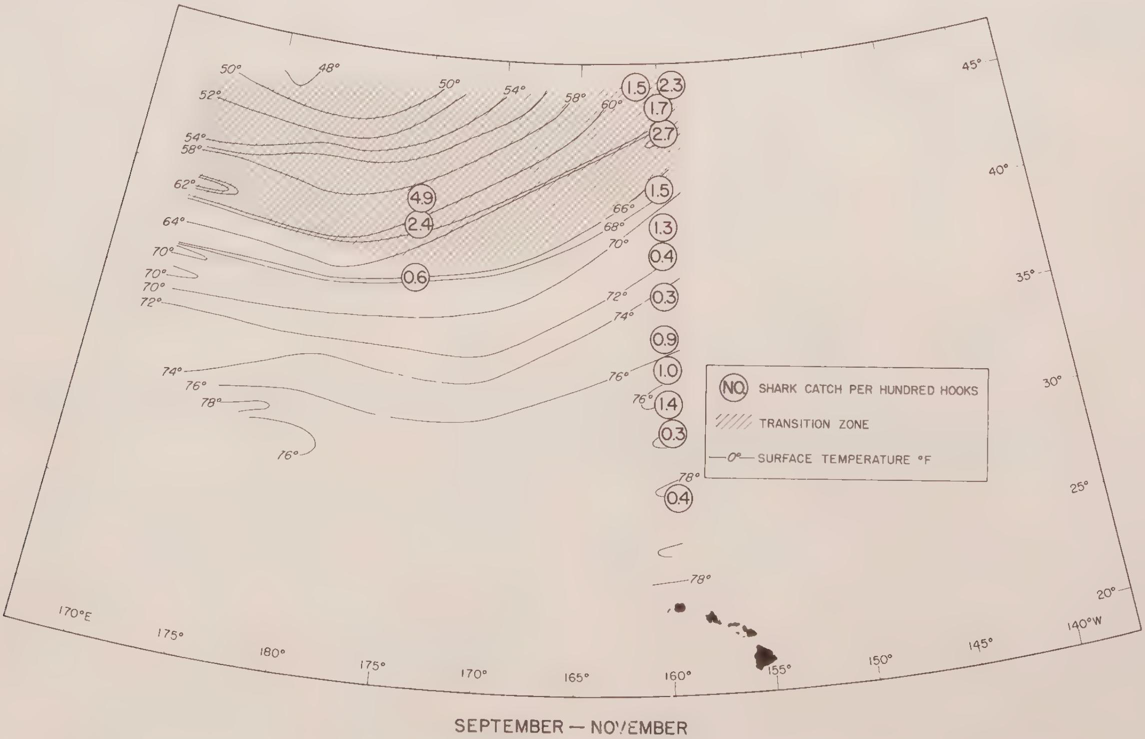

1.5
2.3
1.7
2.7
4.9
2.4
1.5
1.3
0.4
0.6
0.3
0.9
1.0
1.4
0.3
0.4
NO. SHARK CATCH PER HUNDRED HOOKS
TRANSITION ZONE
—0°— SURFACE TEMPERATURE °F
45°
40°
35°
30°
25°
20°
170°E
175°
180°
175°
170°
165°
160°
155°
150°
145°
140°W
SEPTEMBER — NOVEMBER

FIGURE 6c.—Relation between the great blue shark catch rate and position of transition zone, September–November. (After Shomura and Otsu, 1956.)

lation was newly born. The fact that small great blues were rarely encountered in warmer waters suggests that migrations may be a reproductive phenomenon having a close relation to the position of the transition zone.

The present data are inadequate for a discussion of the longitudinal aspects of migration.

The whitetip and silky sharks, occurring as they do solely within the Tropics, do not exhibit marked fluctuations in abundance. Figure 5 indicates that, within the limits of our sampling, whitetip numbers are greatest between 0° and 10° S., whereas the area of maximum silky concentration lies between 0° and 10° N. In neither region is there much change in numbers during the year. The significance of the large winter catch of whitetips between 10° S. and 20° S. cannot be determined until more seasons are represented in the catch data. Peripheral to these areas of concentration there is some evidence of seasonal fluctuations, the whitetip being more numerous in the summer to the north, and the silky more numerous in the spring to the south. Finally, the most northerly records of each species were obtained in the summer.

DISTRIBUTION BY DEPTH

Although the use of chemical sounding tubes to ascertain the fishing depth of the longline (Graham and Stewart [1]) is now standard procedure on POFI cruises, such information was not available for the majority of the cruises on which this report is based. The vertical distribution of sharks has accordingly been evaluated from the relative depth of the hook of capture. The use and applicability of this method have been discussed by Murphy and Shomura (1953a, 1953b, 1955) and Shomura and Murphy (1955), and the treatment employed here is similar to that used by these authors. Hooks were classified as shallow, intermediate, and deep, but because the number of hooks per basket varied between cruises it was necessary to weight each category in inverse proportion to the number of hooks involved. The arrangement of hooks within a basket for the three types of longline used and the relative hook depths are illustrated in figure 7. Table 2 summarizes hook number, relative depth, and relative weight for the three types of gear considered.

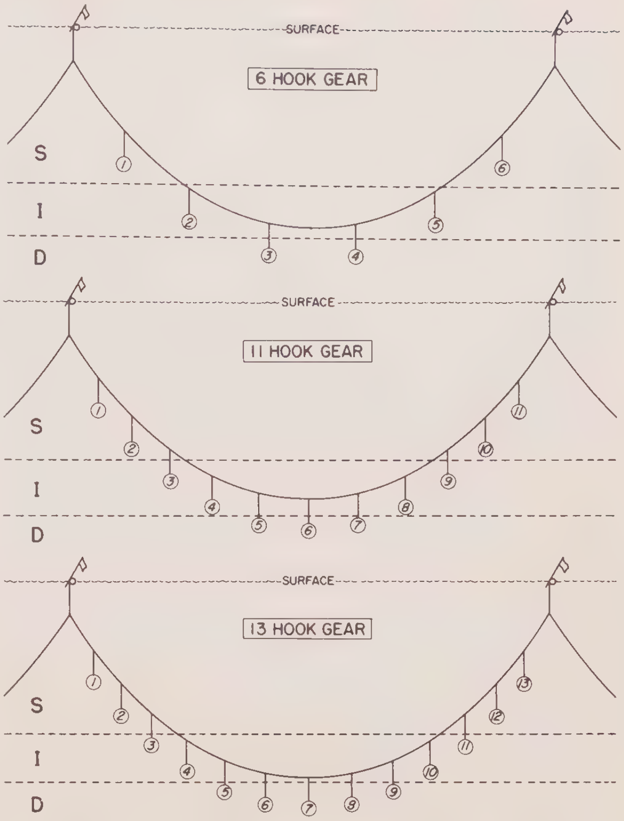


FIGURE 7.—Arrangement of a unit (basket) of each of the three types of longline employed in this study, showing floatlines, mainline, hook-bearing dropper lines, and the general lay of the gear with respect to the surface. Relative hook depths are indicated as shallow (*S*), intermediate (*I*), and deep (*D*).

TABLE 2.—*Depth assignment of hooks*

Type of gear	Relative depth and hook number			Relative weight applied to depth categories
	Shallow	Intermediate	Deep	
6-hook	1, 6	2, 5	3, 4	1:1:1
11-hook	1, 2, 10. 11	3, 4, 8, 9	5, 6, 7	¾:¾:1
13-hook	1. 2, 12, 13	3. 4, 10, 11	5, 6, 7, 8, 9	1:1:⅘

The actual depths implied by shallow, intermediate, and deep have been estimated from the data of Murphy and Shomura (1953a), Iversen and Yoshida (1957) and Stewart and Graham,[2] for 6-, 11-, and 13-hook gear, respectively. Although the depth categories are not strictly comparable between the three gear types, the following ranges are illustrative of the depths sampled:

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[1] Estimating the maximum fishing depth of longline gear with chemical sounding tubes, by Joseph J. Graham and Dorothy D. Stewart. U. S. Fish and Wildlife Service. (Manuscript.)

[2] Unpublished data in files of Pacific Oceanic Fishery Investigations.

shallow, 160 to 280 feet; intermediate, 280 to 430 feet; and deep, 370 to 500 feet. Pooling of results from different kinds of longline gear was minimized by selecting data by latitude and gear type. All catch records from north of 30° N. latitude were derived from 13-hook gear, whereas the majority of records south of 20° N. latitude were based on 6-hook gear, with a few catches from 11- or 13-hook baskets. Between 20° N. and 30° N. latitude the catches from only 11- and 13-hook gear were analyzed. Shark catch expressed as percentage occurrence on shallow, intermediate, and deep hooks is presented graphically in figure 8.

The great blue is wide-ranging and as such would be expected to be broadly eurythermal (fig. 3). The depth distribution data shown in figure 8 are at variance with this in that they show the species as being taken mainly on shallow hooks in the northernmost parts of its range, and mostly on deep hooks south of the Equator. Numerous observations of free-swimming great blues confirm this depth distribution picture, for the species was frequently seen swimming at the surface in the north but never so in the Tropics (not even in pursuit of a hooked and bleeding tuna). This shift in vertical distribution is possibly an example of "tropical submergence," and implies a narrower degree of eurythermality for the species. Lines of evidence supporting this idea are as follows.

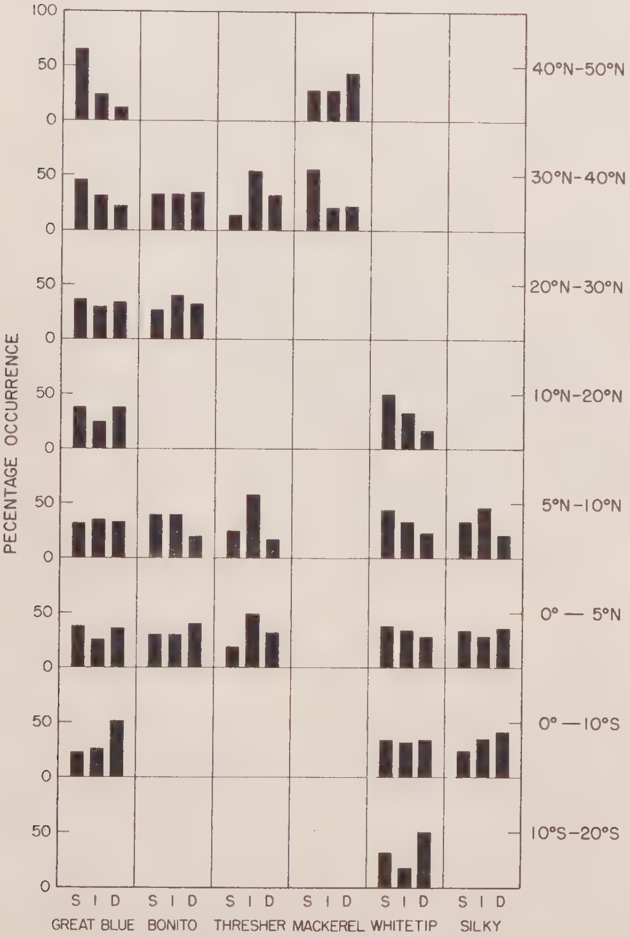

FIGURE 8.—Vertical distribution of pelagic sharks by latitude. Histograms depict percentage occurrence on shallow (S), intermediate (I), and deep hooks (D). Data are based on following catches: 1,318 great blues, 33 bonitos, 486 whitetips, 311 silkies, 27 mackerels, and 62 threshers.

Stewart and Graham[3] have calculated temperatures for the depth of capture of 1,200 great blue sharks taken north of 25° N. From their data the frequency of occurrence of great blues in 5-degree temperature categories was as follows:

Temperature:	*Frequency of occurrence great blue shark*
40° to 44° F	5
45° to 49° F	311
50° to 54° F	524
55° to 59° F	285
60° to 64° F	44
65° to 69° F	24
70° to 74° F	7

Ninety-nine percent of the above sharks were from temperatures between 45° and 69° F., and 86 percent were captured in or below the thermocline. These temperature data are biased to an unknown degree on the cold side (they were derived from estimated maximum hook depths), but they nevertheless indicate that temperatures between about 45° and 69° F. are preferred by the great blue shark. When the depths of the 45°–69° F. isotherms are examined by latitude (c. f. McGary et al., 1956; Cromwell 1954) it is seen that isotherms in the range 50°–69° F. follow the vertical distribution of the great blue (fig. 8). These isotherms either reach the surface or are very shallow between 40° N. and 50° N. latitude but gradually deepen to the south, ultimately lying as deep or deeper than the deepest hooks (this occurs between 20° N. and 30° N. where the isotherm depth range is roughly 500–800 feet). The 50°–69° F. isotherms continue at this depth as far south as the scope of this study except for a marked shallowing at about 10° N. latitude where they approach to within 200–600 feet of the surface. Their broad depth range here renders their shoaling insignificant, and the great blue's depth distribution does not show an accompanying shallowing.

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[3] Unpublished data in files of Pacific Oceanic Fishery Investigations.

Another factor which could account for the increased surface abundance of the great blue to the north is a pronounced seasonal increase in the food supply. Although no direct measures of the standing crop of shark forage (principally small fish and squid) are presently available, an idea of its potential magnitude can be obtained from variations in zooplankton abundance (McGary et al., 1956: 24–26). Between Midway Island and 40° N. latitude zooplankton volumes were about equal for oblique hauls from 0 to 40 meters, which sampled entirely above the thermocline, also for hauls made from the surface to 140 meters and hence, reaching or penetrating the thermocline; in addition, the average volume per haul was uniformly small (16–27 cubic centimeters per 1,000 cubic meters strained) at these latitudes. Between 40° N. and 45° N. latitude the shallow hauls yielded about 1.5 times as much zooplankton as the deeper hauls, and the volume of the catches increased to an average of 64 and 44 cc., respectively. From 45° N. to 50° N. latitude, the shallow hauls caught 1.75 times as much zooplankton as the deeper hauls, and average volumes increased to 168 and 98 cc., respectively. This marked increase in surface zooplankton toward the north is similar in general respects to the distributional picture seen in the sharks themselves.

The vertical distribution of bonito, mackerel, and thresher sharks, shown in figure 8, is based on few records and is probably not very reliable. Bonito and thresher sharks appear to be eurythermal, but three species are involved in the latter and the status of each is dubious. The only explanations offered for the apparent latitudinal shift in vertical distribution of the mackerel shark are (1) that the data may be misleading because of the small sample size (12 and 15 specimens), or (2) that both the shallow- and deep-hook catches were from about the same temperature. With reference to the data of McGary et al. (1956), it is seen that between 40° N. and 50° N. latitude at certain depths the isotherms are very steep so that both the deep and shallow hooks could fish in water of the same temperature.

In common with the other species occurring in the equatorial area, neither the whitetip nor the silky shark shows much latitudinal change in vertical distribution. The whitetip appears to be principally a surface dweller north of the Equator and more bathypelagic to the south, whereas the silky is almost uniformly distributed in depth to the north and is more deep-swimming to the south. The shoaling of the 60°–70° F. isotherms to 200–400 feet at about 10° N. latitude (Cromwell 1954) may explain the whitetip's shallow distribution in that general area, and similarly the deepening of isotherms south of 5° S. latitude could account for both sharks' deeper occurrence there.

VARIATIONS IN ABUNDANCE WITH LONG-TERM TEMPERATURE CYCLES

In the foregoing paragraphs frequent mention has been made of temperature as a factor regulating the spatial distribution of certain sharks. It is of interest, therefore, to examine abundance fluctuations in an area where temperatures are well known and relatively constant, and where shark numbers might be expected to vary directly or indirectly (through food chains, competition, etc.) with slight thermal changes. The region selected for this was the band of equatorial water extending from about 175° E. longitude to 110° W. longitude and bordered by 10° N. and 10° S. latitude. Shark catches from this region were segregated by species, year, and month, reduced to an effort basis, and plotted as anomalies between monthly means and the 4-year mean for each of the three common species. Similar data for surface temperature have been compiled by T. S. Austin, who has kindly made them available to this study. It should be noted, however, that the temperature anomalies are derived from a 6-year mean. Figure 9 shows the relation between shark abundance and temperature fluctuations.

As can be seen from figure 9, the years 1952 and 1953 were characterized by relatively warm surface temperatures (although quite variable in 1952), and 1954–55 by relatively cold conditions. The abundance of both whitetip and great blue sharks was greater during the warm years and lesser during the cold years, the same situation as found for yellowfin tuna.[4] Silky shark abund-

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[4] Murphy and Shomura, unpublished data.

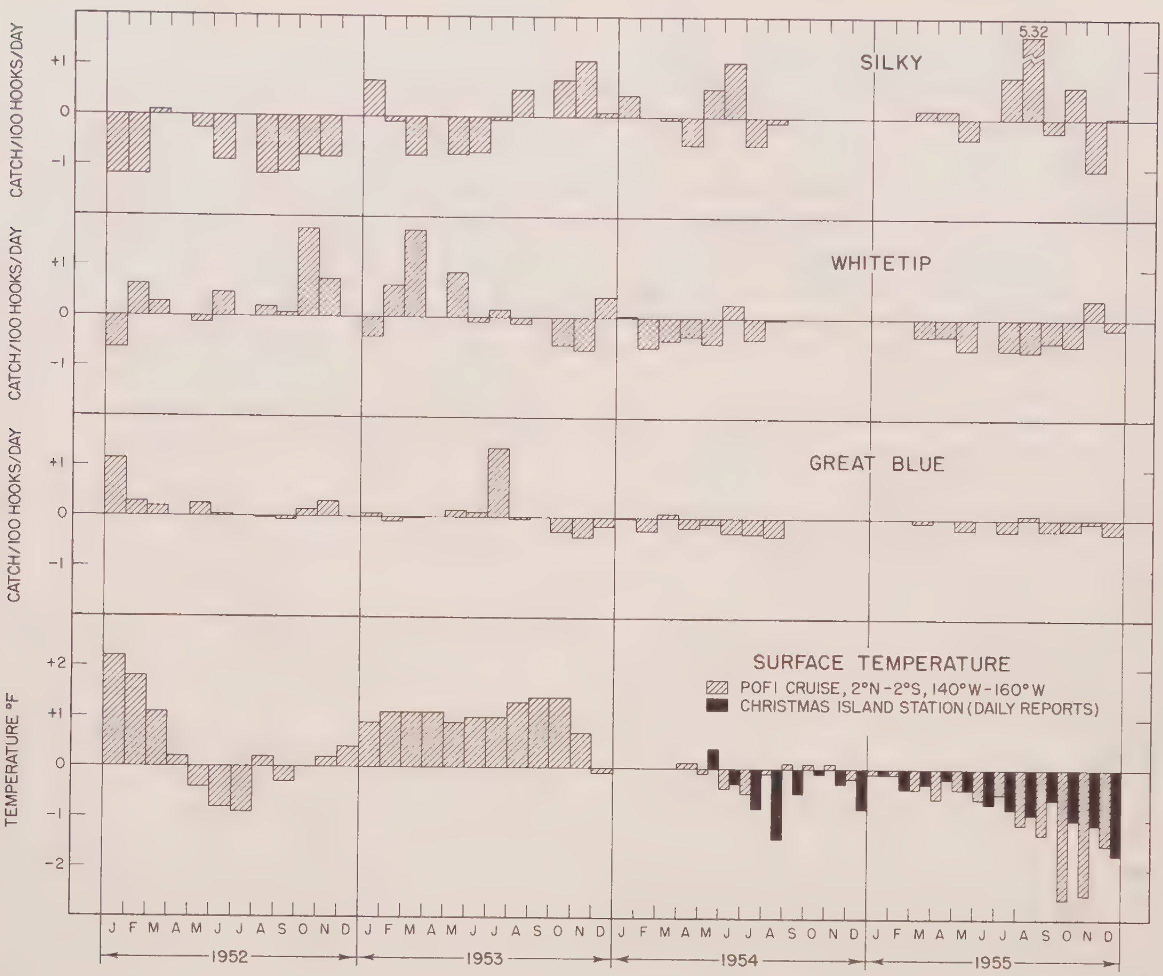

FIGURE 9.—Relation between shark catch and surface water temperature in the equatorial area. Shark histograms depict monthly deviations from 1952–55 means, based on entire catch between 10° N. and 10° S. latitude. Temperature histograms show monthly deviations from 1950–55 means.

ance, on the other hand, appears to be complementary to the other two, but why this should be so is difficult to understand. From the standpoints of latitudinal and depth distribution (figs. 3 and 8), the silky and the whitetip are similar although the silky shark has a narrower latitudinal range. One would assume, on an a priori basis, that the silky was more dependent on warm temperature than the whitetip, and would further deduce that a reduction in its numbers would be brought about by colder rather than warmer water.

Perhaps a portion of the irregularity in the catch data stems from sampling artifacts, for several types of longline gear were in use and fishing was both insular and oceanic. In several instances where whitetip and great blue abundance was anomalous with respect to temperature (notably the last 6 months of 1953) silky shark abundance retained its complementary relation to the other two species, and did not follow the temperature fluctuation. This may represent a behavioral interaction between the silky shark and one or more of the others. A similar situation involving these same sharks is discussed in a later section dealing with abundance versus distance from land.

VARIATIONS IN ABUNDANCE WITH LONGITUDE IN THE EQUATORIAL PACIFIC

A large portion of POFI's research program has been devoted to an evaluation of the fishery resources of the equatorial region of the central Pacific. Intensive sampling of fish stocks, plankton, and the physical and chemical environment has been undertaken, and a considerable body of knowledge of the interrelationships of these properties has been assembled. Physically the region is characterized by the easterly flowing Equatorial Countercurrent between 5° N. and 10° N. latitude, and by the westerly flowing South Equatorial Current to the south of this. Between 5° N. and the Equator there exists a zone of enrichment which reaches optimum conditions, biologically speaking, between 140° W. and 160° W. longitude. Here the sequence of trade winds, divergence, and upwelling brings nutrient-rich water into the euphotic zone, with a resultant increase in biological productivity. An increase in abundance in this area has been shown for zooplankton (King and Demond, 1953), tuna (Murphy and Shomura, 1953a, 1953b, 1955; Shomura and Murphy, 1955), and sea birds (King and Pyle, 1957) so it would not be surprising to find a similar increase in the number of pelagic sharks.

To examine further the geographic variation in shark abundance the catch records for all species were reduced to terms of average catch per hundred hooks per day for 5-degree intervals of latitude and 10-degree intervals of longitude between 10° N. and 10° S. latitude, and 175° E. and 110° W. longitude (fig. 10). The 4,133 records considered include 2,174 silky, 1,151 whitetip, 641 great blue, and small numbers of bonito, thresher, hammerhead, and blacktip sharks. Because of the effects of land on species composition the species data were pooled.

In the region of the Equatorial Countercurrent (5° N. to 10° N. in the central Pacific) shark numbers generally decreased from east to west, the configuration of this decline being nearly identical to that found for zooplankton volumes (King and Hida, 1957). A difference between the zooplankton and shark abundance patterns is that the former peaks at 140° W. and declines east of that point, whereas shark abundance appears to be minimal at 140° W. and to rise to the eastward. Because of the generally close correlation between shark numbers and zooplankton volumes it would seem that basic food abundance, and not temperature or proximity to land (see p. 348) is the factor influencing shark distribution in the Countercurrent area. King and Hida (loc. cit.) state that the east-to-west decline in zooplankton parallels a decrease in surface enrichment caused by a slackening of wind and deepening of the thermocline.

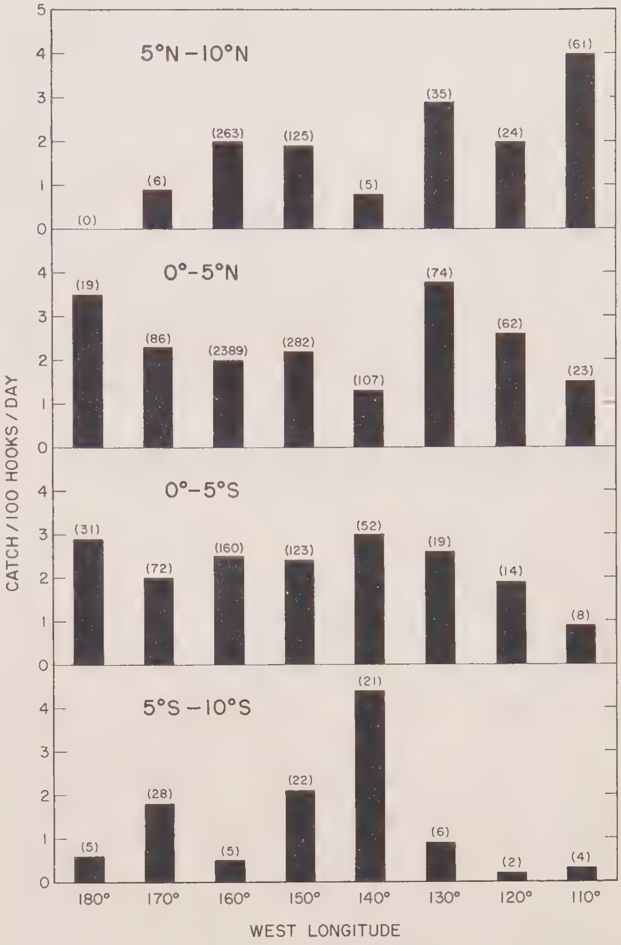

Figure 10.—Abundance of pelagic sharks in equatorial waters, all species combined. Each histogram depicts abundance for the area 5 degrees on each side of the numbered coordinate of longitude and within each 5-degree band of latitude. Numbers in parentheses represent actual catch.

Between 5° N. and 5° S. (South Equatorial Current) there are two types of distributions in the biotic indices. One involves a gradual doming of abundance with maximal values occurring between 140° W. and 160° W., the other the reverse situation with minimal values occurring at these central longitudes, and increases to the east and west. King and Hida (1957) found the first type for yellowfin tuna and zooplankton, and it also occurs for sharks between the Equator and 10° S. (fig. 10). The second situation obtains for inorganic phosphate (King and Hida, loc. cit.) and for sharks between 5° N. and the Equator. It is difficult to reconcile these seemingly antithetical patterns, for one would presume the distribution of organisms high in the food chain to correspond closely to that of the nutrients below them. Perhaps the decline in shark numbers at 140° W. longitude is brought about by food competition between sharks and yellowfin tuna. As shown by Murphy and Shomura (1955), yellowfin are particularly abundant at this longitude between the Equator and about 7° N. latitude. South of the Equator there is close agreement between the longitudinal distributions of sharks, yellowfin tuna, and plankton.

SHARK DISTRIBUTION WITH RESPECT TO LAND

The effect of land or proximity of land on the distribution of a pelagic marine animal provides an interesting problem. For certain oceanic species the presence of land acts only as a barrier to movements, whereas others congregate about islands and other land masses to feed or to reproduce. It occasionally happens that oceanic fish abound in insular environments, either because of the islands' intrinsic nutritive richness or because they lie in the path of rich oceanic currents. The latter situation is apparently true for Christmas Island, a member of the Line Islands group. Here an atoll is located in the path of flow of enriched equatorial water, and maximum abundance of yellowfin tuna occurs in a narrow band extending from Christmas eastward for several hundred miles (Sette 1955).

The POFI longline surveys have provided information on the distribution of sharks in relation to nearness of land. Proximity to land was determined by measuring the distance between the noon position of a fishing station (recovery of longline gear usually started at noon) and the nearest portion of Christmas Island. Shark abundance in neritic situations is contrasted with that of the open ocean in figure 11.

Three distributional patterns are apparent for the sharks shown in figure 11. The thresher sharks (3 species) are definitely neritic, their abundance falling close to zero 40 miles from shore. The silky shark (noted as semipelagic, Springer 1950) occurs in moderate numbers on the high seas but is about twice as plentiful in the neritic region. Two sharks, the whitetip and the great blue, are truly oceanic species, and their numbers steadily increase as land is left behind.

The zone delimited by the categories 10–19 and 50–59 miles from land is essentially a region where the physical and ecological characteristics of the neritic and oceanic provinces intergrade. It is of interest that in this transitional area none of the sharks considered exists in the same degree of abundance as it does in more landward or seaward locales. Perhaps the intermediate nature of the physical environment favors neither the neritic nor the oceanic species, or perhaps abundance fluctuations represent biotic interaction between one or more sharks and other organisms. If the latter, then interaction is most likely in the realm of food competition, for predation and other immediately deleterious relationships are probably inconsequential for large sharks.

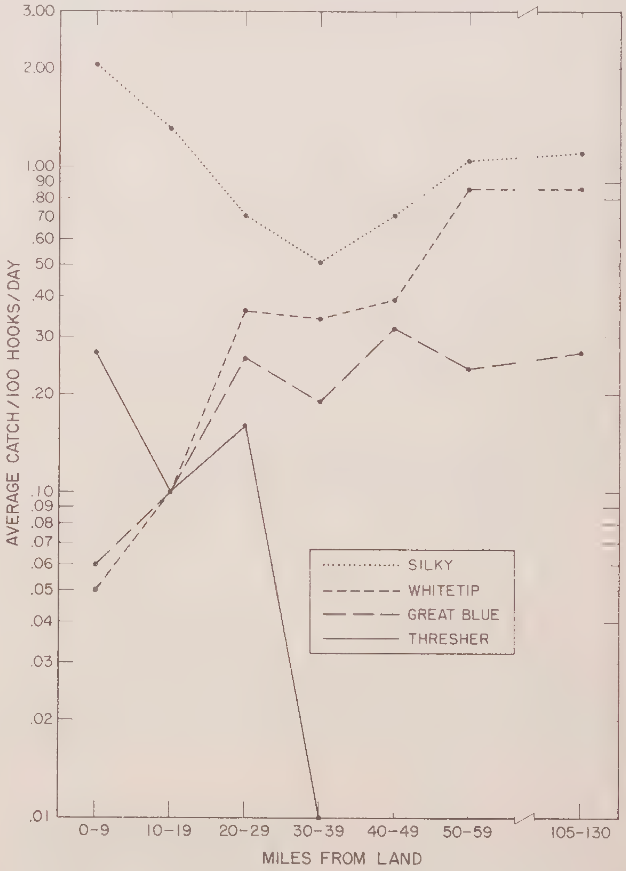

FIGURE 11.—Abundance of pelagic sharks with regard to distance from land. Data derived from Christmas Island area and region to eastward between 1° N. and 3° N. latitude. Based on 997 silky, 210 whitetip, 133 great blue, and 86 thresher sharks.

The species of sharks discussed here subsist principally on small fish and squid and have this diet in common with yellowfin tuna (Reintjes and King, 1953) and bigeye tuna (King and Ikehara, 1956). As to swimming speeds, it would appear almost certain that the tunas are much faster than the sharks, and that among the sharks themselves there may be considerable differences in speed. It has been suggested that whitetips are relatively slow swimmers compared to silky sharks (Backus et al., 1956), with the whitetip's cruising speed being estimated at about a mile an hour by Strasburg (1957). Also confirming this slowness is the fact that, although several silky sharks have been taken while trolling at 6 to 8 knots, only 1 whitetip was so captured during several thousand hours of trolling by POFI vessels. This lack of speed would place the whitetip in an unfavorable competitive position with both the yellowfin tuna and the silky shark, the abundance of each of which increases as Christmas Island is approached (see Shomura and Murphy, 1956 for yellowfin data). It appears, therefore, that the generally inverse relation between whitetip and silky abundance shown in figure 11 may represent a competitive interaction between the two.

FOOD HABITS OF PELAGIC SHARKS

The fact that sharks are broadly carnivorous is common knowledge, but the food of many of the pelagic species is not particularly well known. Unfortunately, the stomach contents of longline-caught sharks were not routinely examined by POFI, and as a consequence the ensuing discussion is not based on a large body of data. Another factor reducing the number of records is that more than half of the 265 stomachs examined were empty. A summary of the results of our food study is presented in table 3.

As evidenced by the information in table 3, pelagic sharks subsist mainly on small fish and squid. Bigelow and Schroeder (1948) and Backus et al. (1956) have shown that the whitetip and bonito sharks also consume large fish such as tuna, and this is also indicated by the present data. In the present case, however, it could not be determined whether tuna were only preyed on after they had been hooked. The more neritic silky shark included littoral forms such as *Diodon* and crabs in its diet, and other sharks did the same in suitable locales. One tendency not shown in table 3 is that a number of thresher sharks were foul-hooked by the tail. Their capture probably resulted from attempts to herd the dangling bait with their tails (Breder 1929).

Pelagic sharks as a group are opportunistic feeders, commonly taking almost any available food, and often ingesting articles of little or no nutritive value. Several species tend to congregate around ships, and have been seen to swallow such items as paper cartons, tin cans, and scraps of cloth, along with considerable amounts of

TABLE 3.—*Food of longline-caught sharks*

Shark species	Number of stomachs in which occurred—																									Number of empty stomachs	Number of stomachs examined
	Fish													Longline bait			Flying fish eggs		Cephalopods			Miscellaneous					
	Alepisaurus (Lancet fish)	*Neothunnus* (Yellowfin tuna)	*Katsuwonus* (Skipjack)	Unidentified tuna	Tuna-like fish	*Diodon* (Spiny puffer)	*Mola* (Ocean sunfish)	Bramids (Pomfrets)	Echeneids (Sucker fish)	Myctophids (Lantern fish)	Ostraciids (Trunkfish)	Stingray	Unidentified fish	Herring	Sardines	Unidentified bait	Attached to feathers	Unattached	Squid	Octopus	Unid. cephalopods	Crabs	Shrimp	Sea bird (booby)	Blubber (?)		
Great blue	5								1	1	1		25	4	10		4	2	19	1	20	2	2	1	1	76	140
Whitetip	2	1		2				1				1	6	2	24				10	1	2					35	73
Silky						2							1		2				3			1				22	29
Bonito	1	1			1		1						1			1			2							6	13
Thresher	1		1										3	2					1							2	7
Blacktip													1													0	1
Hammerhead:																											
S. zygaena				1																						0	1
S. lewini													1						1							0	1
Total	9	2	1	3	1	2	1	1	1	1	1	1	38	8	36	1	4	2	36	2	22	3	2	1	1	141	265

garbage and fish scraps. The indiscriminate nature of this type of feeding suggests a low degree of visual (and olfactory?) acuity coupled with voracious feeding behavior, both of which are well known for sharks, and which would seem to belie their ability to capture squid, tuna, and sea birds unless these were moribund or dead. On the other hand, the author has seen a team of 2 or 3 whitetips slowly herd and capture squid around a surface light at night, and has also removed large pieces of tuna flesh from whitetip stomachs in areas where no fishing was taking place. Finally, a bigeye tuna (*Parathunnus sibi*) captured on a POFI longline cruise bore a pair of large **U**-shaped scars suspiciously resembling shark jaws in shape. The indications are that some pelagic sharks can be both fast moving and selective feeders, and perhaps the unpredictable rapacity of their feeding enables them to capture what would seem to be elusive, highly motile prey.

Some mention must also be made of a rather artificial food habit of sharks, namely the damage they inflict on longline-caught tuna. Other workers have noted that damage is virtually absent from the more northerly portions of POFI's investigative area (Shomura and Otsu, 1956) but averages about 20 percent of the longline catch in equatorial waters (Murphy and Shomura, 1955; Iversen and Yoshida, 1956). It is obvious that shark damage to hooked tuna is ultimately limited by both shark abundance and the availability of tuna, and that the interaction of these two factors coupled with the behavioral characteristics of sharks is what determines the extent of the damage. For the purposes of the present study all species of longline-caught tuna (*Neo-*

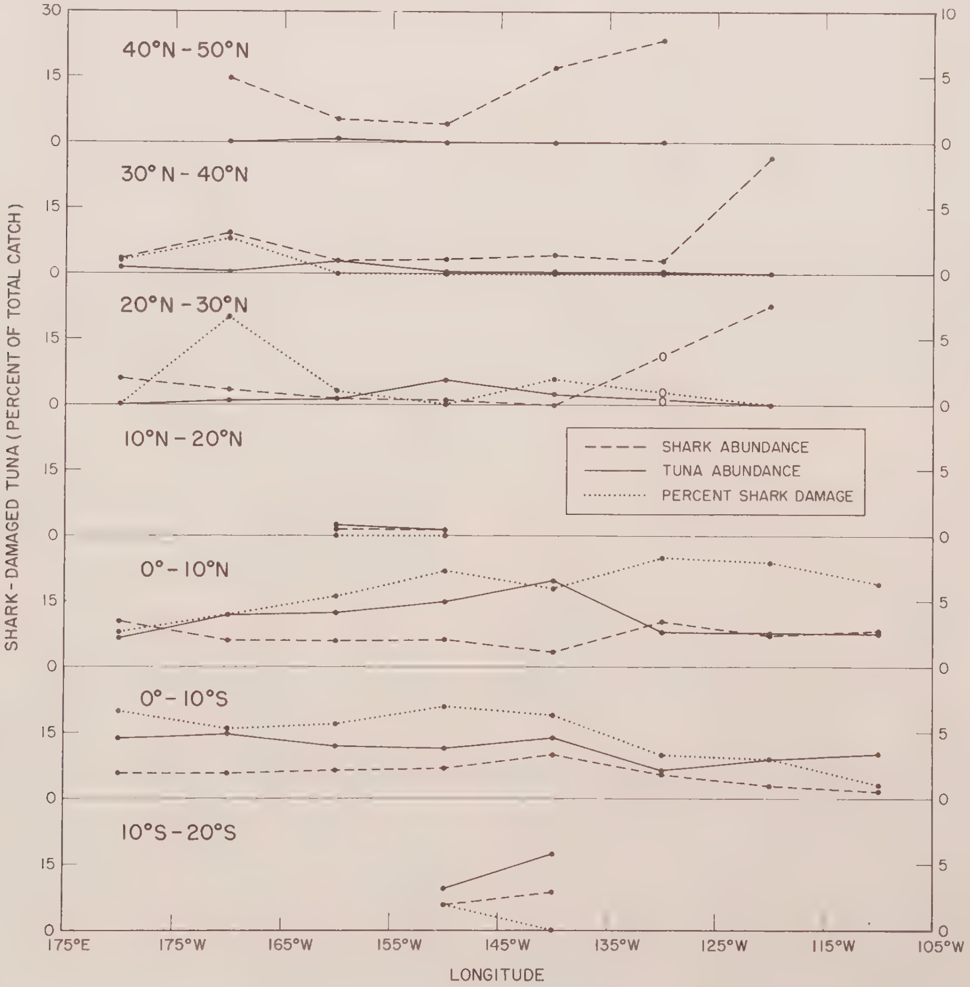

FIGURE 12.—Shark damage to tuna contrasted with shark and tuna abundance. 0=no sample.

thunnus macropterus, *Parathunnus sibi*, *Germo alalunga*, and *Katsuwonus pelamis*) are lumped as "tuna," and all shark species are combined.

North of about 30° N. latitude POFI's longline tuna catch has been minimal, and shark damage affected only about 1 percent of it (fig. 12, and Shomura and Otsu, 1956). Between 20° N. and 30° N. latitude tuna abundance increased whereas shark damage was only slight or moderate (fig. 12). The prominent peaking of shark damage between 20°–30° N. latitude and 165°–175° W. longitude is an artifact caused by a very small sample (1 damaged tuna out of 5 caught). In these northern areas the abundant shark is the great blue (fig. 3), and it would seem that this species is not particularly deleterious to the fishery, other accounts to the contrary (c. f. Bigelow and Schroeder 1948: 286).

In equatorial waters tuna abundance is equal to or greater than shark abundance (fig. 12), and shark damage is at its greatest here, frequently involving as much as 20 percent of the tuna catch. The principal culprits in this region are the whitetip and silky sharks, with the bonito being of much less importance (figs. 3 and 4, and numerous observations by POFI biologists). From the equatorial situation one might suppose a good positive correlation to exist between shark and tuna abundance, but this was not found by Iversen and Yoshida (1956). These authors found a strong relation between shark catch rate and shark damage on a monthly basis, but this breaks down, in part, when studied on a nonsecular basis. When tuna abundance is low there is a correlation (r=0.573) between shark abundance and shark damage (fig. 13), but when tuna abundance is high there is almost no relation between the two (r=0.019). A possible explanation of these phenomena is that an abundance of tuna probably indicates an abundance of forage organisms so that a large natural food supply (either tuna or forage) is available to the sharks. The sharks are well-fed and not interested in longline-caught fish. Conversely, a dearth of tuna and other forage animals would enhance the attractiveness of hooked tuna, and proportionally more of the catch would be eaten by sharks.

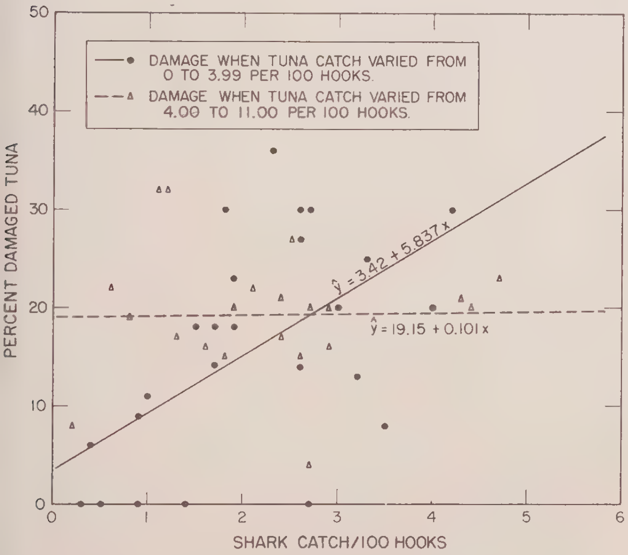

Figure 13.—Relation between shark damage of longline-caught tuna and shark abundance. Based on catch records of 8,797 tuna (of which 1,511 were damaged) and 4,133 sharks. All catches made between 10° N. and 10° S. latitude. When tuna catch low, $b=5.837$, $p<0.01$; when tuna catch high, $b=0.101$, $p>0.5$.

SEXUAL SEGREGATION

Among sharks there appear to be two basic types of sexual segregation or tendency to school by sex. In behavioral segregation individuals school with others of similar size, thus sorting the sexes in the case of a dimorphic species such as *Squalus acanthias* (Ford 1921). In what has been called geographical segregation (Backus et al., 1956) the sexes school separately because of differences in habits. Geographical segregation has been found for *Scyliorhinus canicula* by Ford (op. cit.), for the soupfin (Ripley 1946), for *Galeorhinus australis* by Olsen (1954), the great blue (Bigelow and Schroeder, 1948), and the whitetip (Krefft 1954; Backus et al., 1956). These authors have related geographical segregation to season, region, depth, distance from land, and degree of sexual maturity, with the underlying causative factor generally being regarded as reproductive in nature. In two cases (Olsen 1954; Backus et al., 1956) the existence of definite breeding grounds has been mentioned.

The present data are scanty as to sex of the sharks caught, but nevertheless they indicate that both behavioral and geographical segregation may occur in the same species. This study is primarily restricted to the great blue because sex was not recorded for adequate numbers of the other species. An inherent fault in the data is that because of the length of the longline gear (7 to 10 miles in each set) a single day's catch may actually contain samples from several schools.

Table 4 illustrates the degree of unisexual predominance in the catches from 36 longline stations where sharks were sexed and at least 4 specimens of a species were taken. In the great blue shark the sex ratio varied from about 1 : 1 to a tremendous preponderance of one sex. The data on the whitetip and the silky were not so extensive and did not show this degree of variability.

Table 4.—*Instances of unisexual predominance in shark catches* [1]

Species and number of specimens examined	Frequency of occurrence of predominant sex (in percent)					
	50–59	60–69	70–79	80–89	90–99	100
Great blue (283)	6	3	5	3	2	10
Whitetip (29)		1	2	1		1
Silky (11)				1		1

[1] Units are number of stations showing predominance. The smallest station considered yielded 4 sharks of any one species.

In determining whether preponderance of either sex was of the behavioral or geographical type of segregation the great blue shark data were analyzed in several ways. When the percentage of males was plotted by latitude (fig. 14), males comprised a smaller proportion of the northern catch than they did of the southern. This difference is most striking when the unisexual catches are considered, but it is also apparent in mixed catches and the entire catch (unisexual and mixed data pooled). There can be no doubt that latitudinal variation in sex ratio represents geographical segregation but the biological aspects of this phenomenon are not so easily classified.

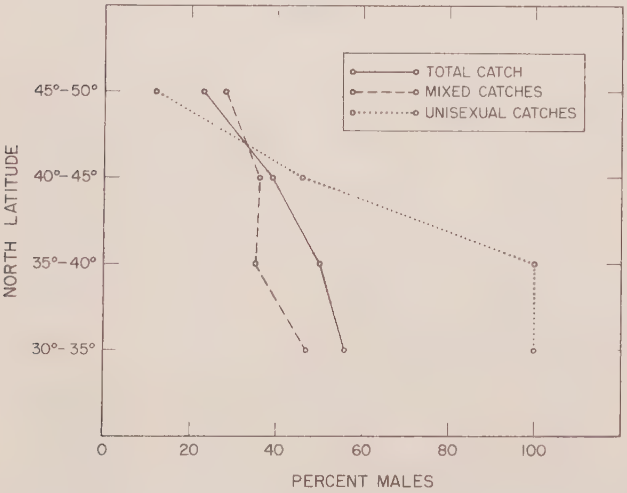

Figure 14.—Sex composition of great blue shark catch by latitude. Based on 255 records of which 184 were from mixed and 71 from unisexual catches.

If the mean total length of great blues is plotted by sex and latitude (fig. 15), it appears that in mixed catches (pooled from several stations) both sexes are about the same size at any latitude, and the mean length decreases to the north. The lengths of sharks from unisexual catches are slightly to considerably greater than those of mixed catches, but there is little relation between the lengths of males and females. If our catches actually represent schools then it is not illogical to presume that unisexual schools are derived from mixed schools by a behavioral size-sorting mechanism. Judging from the overlap between the standard deviations of mixed and unisexual school lengths, this mechanism becomes operative at lengths between about 110 and 160 centimeters. It is unlikely that segregation of such small sharks has a direct reproductive significance, for the smallest gravid females known were from 208 to 214 cm. in length (Bigelow and Schroeder, 1948, and in this paper p. 354).

Because the causative agent for behavioral segregation is thought to be size dimorphism between the sexes (Backus et al., 1956), it was reasoned that the difference between male and female lengths in individual mixed catches should be related to the sex ratio of the catch. This relation is shown in figure 16 which indicates that the greater the size difference between the sexes the greater the disparity in sex ratio. Where females are larger than the males most of the catch is male, and where males are larger than the females most of the catch is female. A similar situation obtains for the soupfin shark (Ripley 1946). Such a situation not only poses the question of why large sharks should be of opposite sex from the rest of the school, but it is also rather contrary to the principal tenet of behavioral schooling, that members of a school be of like size. The regression in figure 16 is significant ($p=0.02$) only when the two points to the extreme left are included.

The available data are too few to form more than an outline of the secular aspects of sexual segregation. They are derived from a sample of 255 great blues taken between 30° N. and 50° N. latitude over a period of several years. Both mixed and unisexual catches were made in the

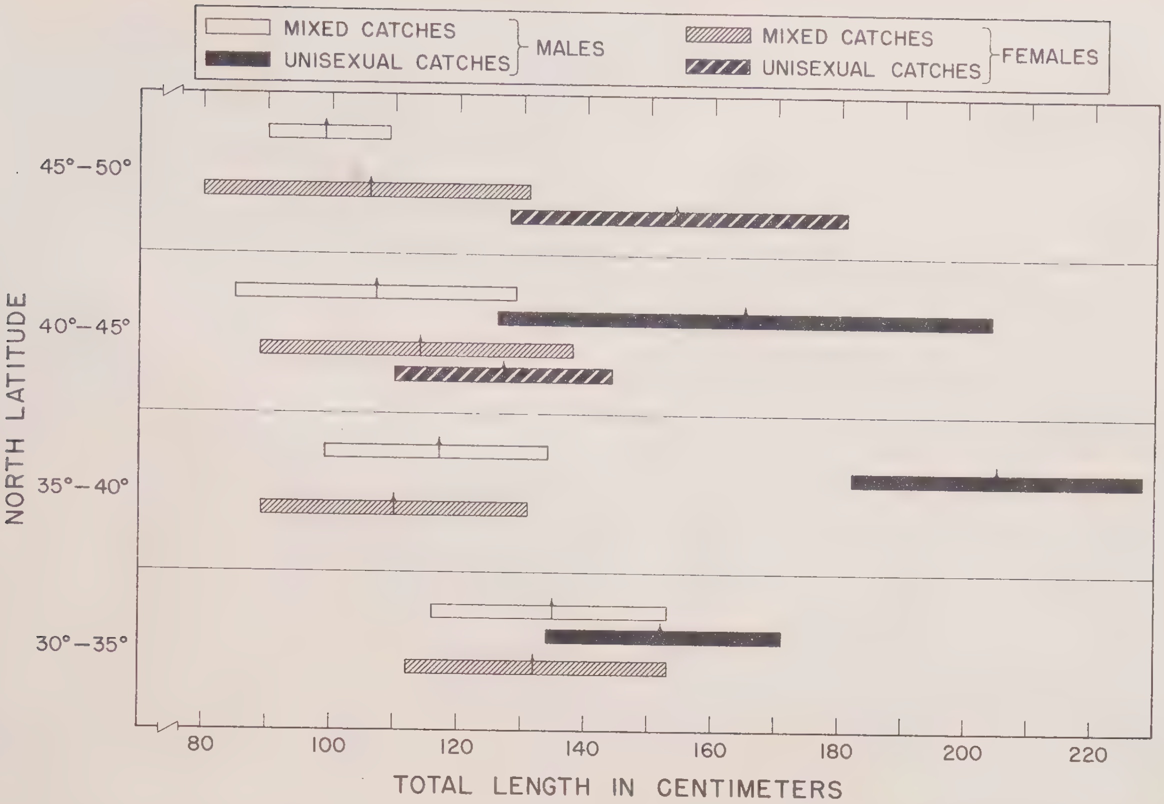

Figure 15.—Length composition of unisexual and mixed catches of great blue sharks at various latitudes. Vertical lines are means; blocks are one standard deviation on each side of mean.

summer and autumn but only mixed catches were taken in the winter and spring. On a percentage basis mixed catches contained the following proportions of males: spring 36 percent, summer 33 percent, autumn 22 percent, and winter 47 percent. The autumnal disparity in sex ratio is also of interest in that the two unisexual catches made in that season were composed of males. The low male ratio in summer mixed catches is similarly reflected in the unisexual data, for here only 2 all-male (versus 4 all-female) catches were made. From these sketchy data it appears that the great blue catch is composed of about equal numbers of both sexes in the winter, and that females gain predominance in the spring. Unisexual schools form during the summer and autumn and probably reassemble as mixed schools in the winter. The data are too few to present a latitudinal picture of these changes.

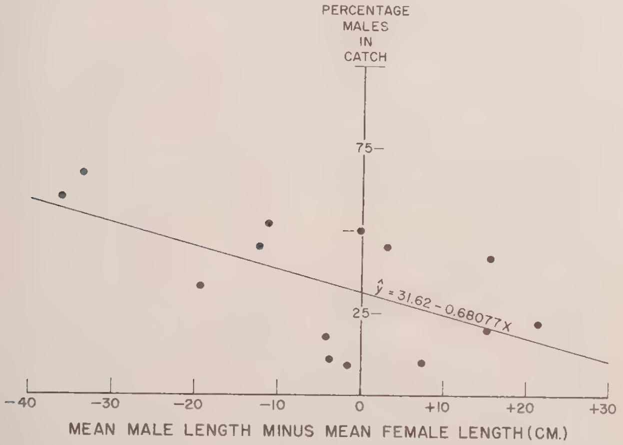

Figure 16.—Relation between sex and size composition of individual mixed great blue shark catches. Based on 172 sharks taken in catches containing from 5 to 24 individuals. Regression line fitted by method of least squares.

When the mean lengths of great blues are plotted by sex and season (fig. 17), it is evident that autumn is not only the period of greatest disparity in sex ratio but is also the time of greatest length difference between the sexes. Unfortunately, the data were necessarily derived from pooled mixed and unisexual catch records and are thus rather unreliable (in the case of unisexual records there is no particular reason for

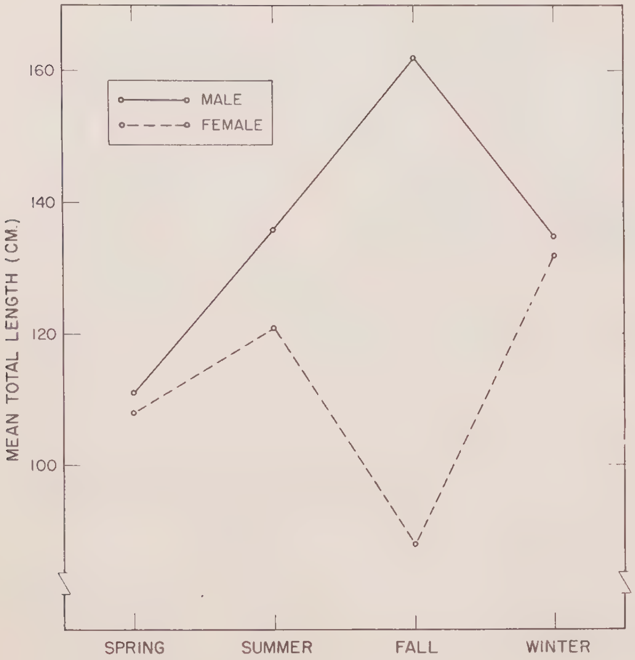

FIGURE 17.—Mean total length of great blue sharks by sex and season. Based upon 112 males and 143 females from mixed and unisexual catches taken between 30° N. and 50° N. latitude.

one school to resemble another in its length composition). The increase in mean length over the spring-to-fall interval probably reflects an availability fluctuation more strongly than growth.

REPRODUCTION

The available data on reproduction in the female are based on observations on the following: 18 great blues, 19 silkies, 32 whitetips, and 4 threshers (2 *A. pelagicus*, 1 *A. vulpinus*, 1 *A. superciliosus*). All of these except 6 great blues and 1 whitetip were taken in equatorial waters, with most specimens coming from the Line Islands area. Although the data are meager they are presented because of the general lack of knowledge of the reproductive habits of pelagic sharks.

Of the 12 great blue sharks from the equatorial Pacific the smallest gravid female measured 214 cm. and the largest 244 cm. Nongravid females from this region ranged from 188 to 243 cm. in total length. Embryos were found during February, March, May, August, October, and December, with the largest fetuses (22–28 cm.) occurring in March and May. Nongravid females as large or larger than the pregnant ones were encountered from January through August. The number of embryos per female ranged from 4 to 38, and in 1 litter of 18 their distribution was 8 on the left side and 10 on the right. There was no apparent correlation between embryo size and time of year.

The 6 nonequatorial great blue females were taken between 24° N. and 35° N. latitude. The 4 gravid specimens ranged from 208 to 247 cm. in total length and contained from 23 to about 40 embryos, the distribution of which was bilateral (16 on the left side and 17 on the right in 1 specimen). All 6 females were taken in January and February and here again there was no relation between embryo size and time of year. One female obtained in February gave birth to between 30 and 40 pups on deck (fig. 18), and these were the largest great blue embryos taken, suggesting that they were very near term. Further confirming this conclusion is the fact that their length range (34–48 cm.) approximates the foot-and-a-half length of the smallest longline-caught great blues. Also, the pups were very active at birth and appeared ready to fend for themselves. All emerged tail first.

All 19 female silky sharks were taken from the equatorial region, and of these 12 were gravid and 7 not. Both gravid and nongravid females were taken throughout the year, the range in total length of the former being 213 to 236 cm., and of the latter, 186 to 218 cm. The number of young observed varied from 2 to 11, with a mean value of 6.5 per female. The total length was recorded for 32 embryos and ranged from 37 to 66 cm., the upper extreme suggesting that the pups are quite sizeable when born. There again appeared to be no relation between embryo size and time of year. Uterine distribution of embryos was recorded for 2 females, one of which had 4 embryos on each side, the other having 2 on the left and 5 on the right. The single litter sexed contained 2 male and 7 female embryos.

Only 3 of the 32 female whitetips examined contained embryos, these 3 being equatorial specimens. A 210-cm. specimen was taken in April and contained 6 fetuses from 36 to 40 cm. in total length, a 196-cm. female obtained in May had five 20- to 28-cm. embryos, and a 195-cm. female taken in December contained 7 averaging 18 cm. in total length. These fragmentary data suggest a rather different developmental picture from that noted by

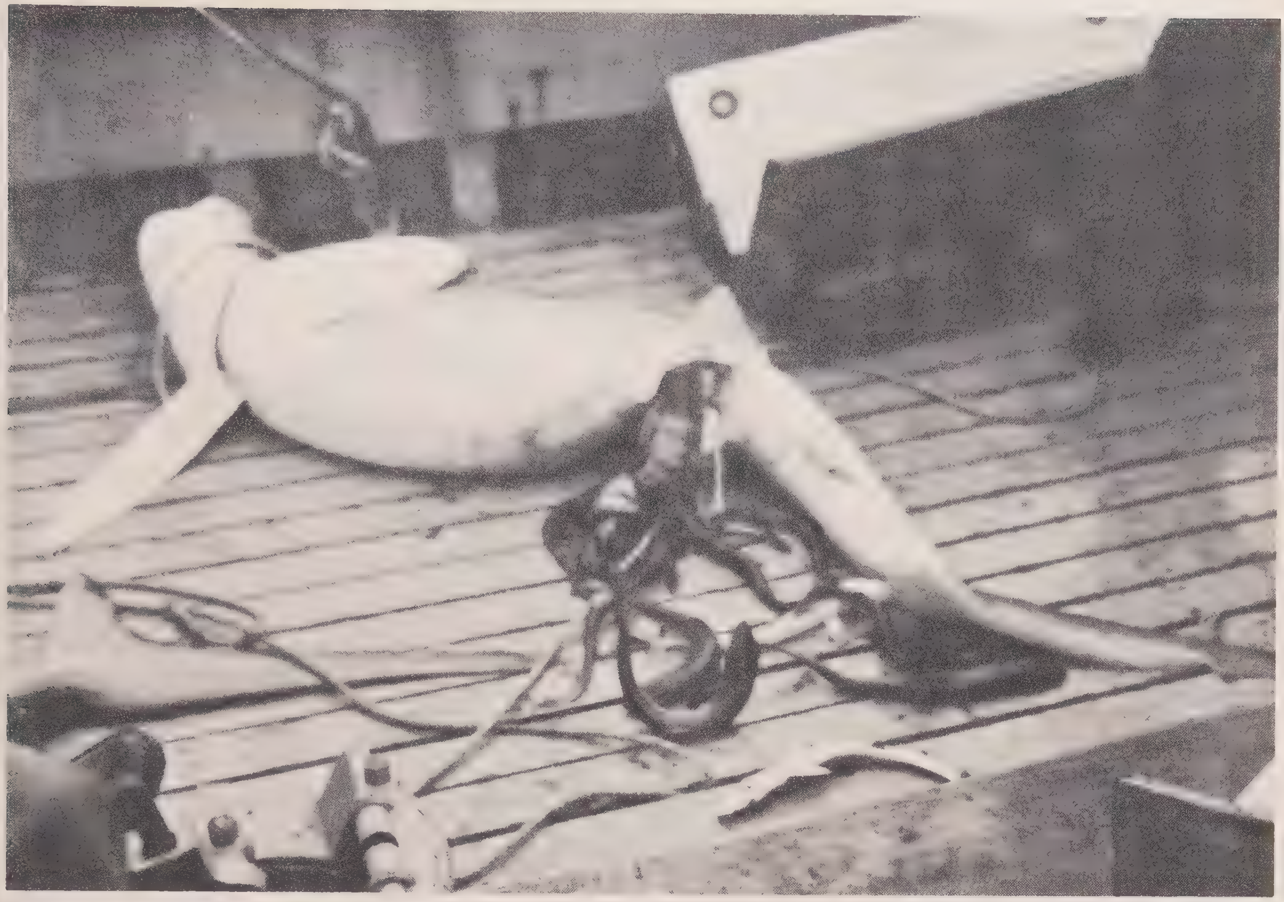

FIGURE 18.—Female great blue shark giving birth to young on deck of the *John R. Manning*. Nine young can be seen on deck while a tenth, still enveloped in its embryonic membranes, is just emerging.

Backus et al. (1956) for the whitetip of the Gulf of Mexico and the West Indies, as the central Pacific embryos were rather small at all times of the year. One Hawaiian and 28 equatorial whitetip females contained no young. These infertile females were taken throughout the year and ranged in length from 99 to 246 cm.; about one-fourth of this group were as large or larger than the gravid females.

With regard to thresher sharks, the single female *Alopias vulpinus* examined was captured on June 4, 1954, just to the west of Christmas Island (Line group). This thresher measured 315 cm. in total length and contained 2 fetuses, one of which was 114 cm. in total length. Also present were a number of eggs about 0.7 cm. in diameter. Two females of the rather uncommon *A. pelagicus* were examined, the larger (893 cm. total length) being taken on April 7, 1955, off Fanning Island (Line group), and the smaller (167 cm.) on May 4, 1953, at about 9° N. latitude and 150° W. longitude. The larger female contained the apparently typical number of 2 embryos (see Nakamura 1935), and the smaller one was not gravid. On June 7, 1954, a nongravid female of *A. superciliosus* was taken near Christmas Island. Its total length was 328 cm.

MORPHOMETRY AND TAXONOMY

In the early part of the shark investigation morphometric data were recorded for a number of specimens of each species. In order to make these data comparable to those of other investigators, measurements were standardized with those given by Bigelow and Schroeder (1948). Figure 19 depicts the methods used for measuring certain characters; other measurements follow. Eye diameter — greatest horizontal diameter; labial furrow length—length of outer labial furrow; gill slit height—height of gill opening when

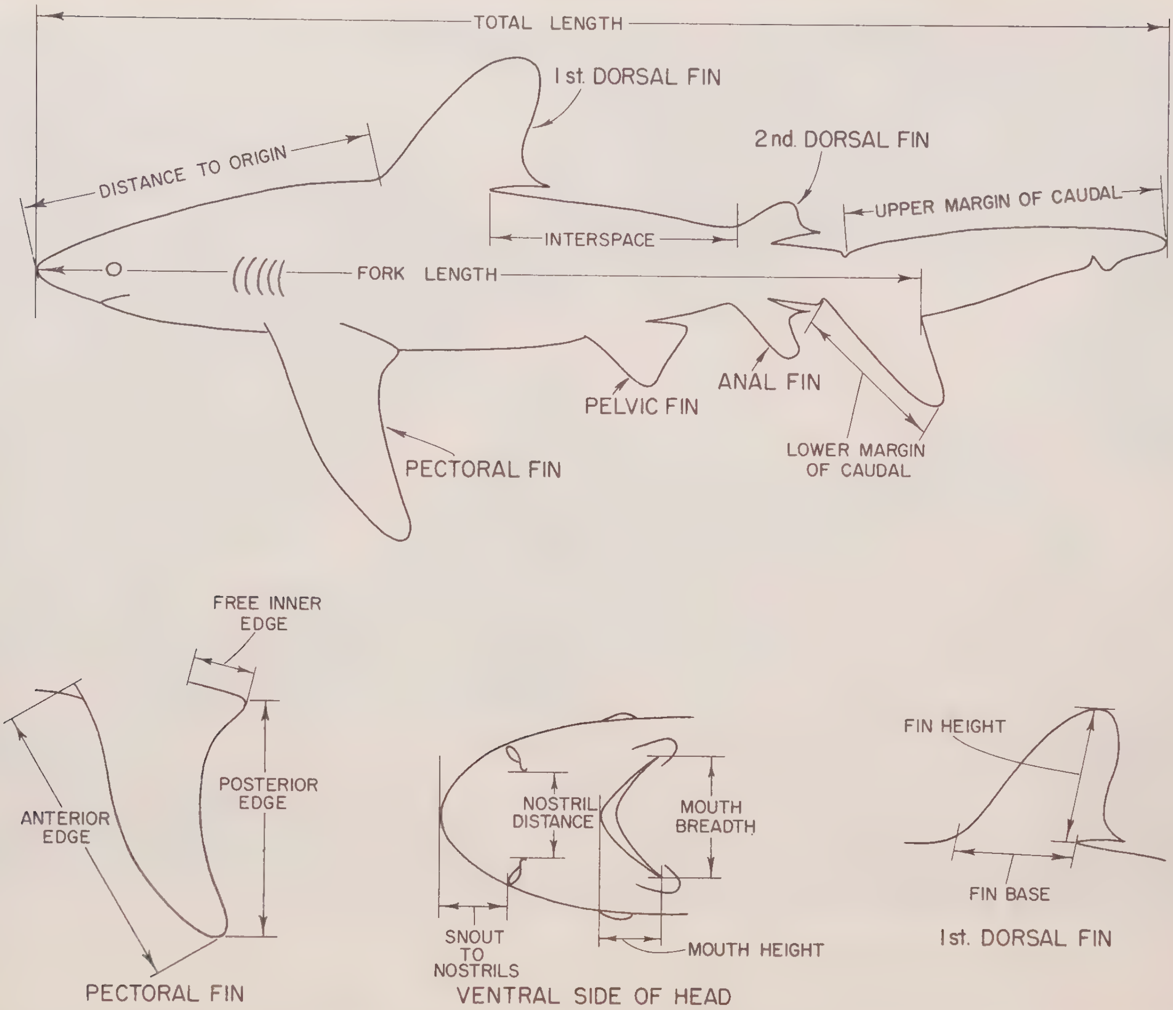
TOTAL LENGTH
1 st. DORSAL FIN
2 nd. DORSAL FIN
DISTANCE TO ORIGIN
UPPER MARGIN OF CAUDAL
INTERSPACE
FORK LENGTH
ANAL FIN
PELVIC FIN
LOWER MARGIN OF CAUDAL
PECTORAL FIN
FREE INNER EDGE
POSTERIOR EDGE
ANTERIOR EDGE
PECTORAL FIN
NOSTRIL DISTANCE
MOUTH BREADTH
SNOUT TO NOSTRILS
MOUTH HEIGHT
VENTRAL SIDE OF HEAD
FIN HEIGHT
FIN BASE
1 st. DORSAL FIN

FIGURE 19.—Method of measuring sharks. All distances are straight lines between perpendiculars, with fish lying on belly when possible.

stretched just enough to prevent buckling of anterior edge; trunk breadth and height—maximum breadth and height at pectoral origin; lower margin of caudal—distance from rear edge of ventral precaudal pit to tip of lower caudal lobe; free clasper-distance from point where clasper leaves anal fin (lateral side) to tip of clasper.

Table 5 summarizes the morphometric data obtained in this study. For the common species the mean and the range are given for each character considered, although the range was not necessarily derived from individuals of maximal and minimal length. The original data were tabulated by sex, but with a very few exceptions overlapping was complete or nearly so, and it did not appear necessary to segregate the final data in this manner.

The volume of morphometric data available for whitetip, silky, and great blue sharks makes possible a comparison between the central Pacific and other forms. Morphometric data for Atlantic specimens were obtained from Bigelow and Schroeder's descriptions (1948) even though these were derived from only a few specimens. For all three species it appears that in the Pacific specimens the distance between the snout and all fins except the anal is greater than in Atlantic material, and also that the second dorsal, the anal, and the upper caudal lobe are smaller in the Pacific. In Pacific whitetips the lower caudal lobe and the various pectoral fin measurements are relatively greater than in the Atlantic, whereas in Pacific silkies and great blues these structures

TABLE 5.—*Shark morphometrics*

[Values expressed as hundredths of total length. Columns indicating range express the range for each character, and not the measurements of the largest and the smallest shark. See pp. 355–56 for measurement methods]

Item	Whitetip (8 males, 8 females)			*P. insularum*[1]	Silky (7 males, 5 females)			Great blue (17 males, 5 females)			Bonito (11 males, 2 females)			Mackerel (1 male, 1 female)	Thresher (*A. pelagicus*) (1 male, 2 female)	Thresher (*A. superciliosus*) (1 female)	Thresher (*A. vulpinus*) (1 female)	Hammerhead (*S. zygaena*) (1 male)	Hammerhead (*S. lewini*) (1 male)	Blacktip (1 male, 1?)
	Smallest	Largest	Mean	Type	Smallest	Largest	Mean	Smallest	Largest	Mean	Smallest	Largest	Mean	Mean	Mean					Mean
Total length (cm.)	72.0	243.1	116.0	213.0	87.7	227.0	192.7	121.7	304.5	234.3	125.1	257.9	205.9	96.0	290.2	327.7	317.0	266.3	301.8	143.2
Fork length	77.3	83.5	80.0	-----	78.5	83.6	80.7	80.1	83.2	81.9	86.8	92.2	88.0	86.2	53.6	57.4	52.5	77.8	80.4	78.6
Snout—1 D	31.3	34.2	32.6	33.3	32.4	35.0	34.1	36.2	39.8	37.9	35.6	38.6	37.3	34.4	25.6	30.4	24.6	27.3	28.2	33.4
Snout—2 D	61.9	65.3	63.2	65.3	63.9	66.7	64.9	62.4	67.2	64.7	69.5	73.2	70.5	67.8	43.0	46.1	41.3	63.5	64.1	63.8
Snout—upper C	71.3	76.6	72.5	74.2	73.0	77.8	74.0	74.0	76.4	75.5	77.9	80.1	79.3	76.6	48.1	51.1	45.9	73.1	74.2	75.0
Snout—pectoral	20.9	24.2	22.5	22.5	20.7	23.7	22.0	19.8	25.0	22.1	23.5	28.0	26.3	29.8	14.4	15.8	14.6	19.8	19.6	20.5
Snout—pelvic	49.5	54.5	51.8	-----	47.6	52.1	49.5	48.0	54.3	50.8	53.9	57.6	55.8	54.8	36.7	38.0	34.8	45.4	46.4	48.7
Snout—anal	61.8	66.2	63.8	-----	61.8	65.8	64.0	61.4	67.5	64.0	70.2	74.1	71.7	67.6	44.6	48.9	43.7	59.8	61.4	63.6
Interspace 1 & 2 D	19.4	22.7	21.1	22.1	22.5	25.3	23.9	19.0	26.4	20.9	24.6	27.0	25.7	25.9	16.7	9.5	12.8	-----	28.1	23.8
Interspace 2 D & C	5.4	7.9	6.4	6.0	6.6	7.9	7.1	7.1	10.0	7.7	7.7	9.0	8.4	7.8	4.1	4.6	4.5	8.5	8.2	7.2
Interspace A & C	3.9	5.1	4.5	3.8	5.3	7.3	6.5	6.9	10.0	7.4	7.2	9.3	7.8	7.8	3.0	2.7	3.1	7.8	7.8	6.5
Origin Pect.—pelvic	28.1	35.2	30.6	-----	26.2	29.9	28.1	26.1	32.9	29.0	22.8	32.0	29.6	26.6	22.7	23.3	20.8	25.7	27.2	27.8
Origin Pelvic—anal	12.1	14.3	13.0	-----	13.6	17.2	15.3	12.1	15.3	13.5	15.6	17.8	16.9	15.1	8.8	11.0	9.5	14.6	14.3	15.9
Snout—nostrils	2.5	3.4	3.0	-----	3.4	4.7	3.9	3.4	4.9	4.2	4.3	5.4	4.8	5.2	2.8	3.1	2.8	-----	4.1	3.2
Snout—mouth	6.1	7.3	6.8	-----	6.5	8.4	7.1	7.9	10.4	8.6	6.2	7.2	6.6	6.7	4.2	4.5	4.1	4.5	4.1	6.4
Mouth breadth	8.8	10.1	9.3	-----	7.4	8.9	8.4	3.0	7.7	6.4	6.4	7.9	7.1	9.5	3.4	4.2	3.6	7.4	7.2	8.8
Mouth height	4.1	6.1	4.9	-----	4.1	6.0	4.9	3.0	4.9	3.8	5.4	6.9	6.1	5.6	2.3	2.4	2.0	3.4	4.7	5.4
Eye diameter	.9	1.8	1.3	-----	.9	1.9	1.3	1.0	2.0	1.5	1.5	2.1	1.7	2.2	1.4	2.0	1.4	1.2	1.1	1.4
Nostril distance	5.6	6.0	5.8	-----	5.1	5.8	5.3	3.3	3.8	3.5	3.3	4.6	3.7	3.8	1.2	1.5	1.2	20.5	20.7	5.4
Labial furrow length	0	2.2	.8	-----	.4	1.1	.6	0	1.4	.6	0	3.7	2.1	1.6	1.9	.9	.6	-----	.3	.6
Height gill slit 1	2.9	4.8	3.3	3.5	2.6	3.5	3.1	2.0	3.3	2.5	6.5	8.2	7.4	8.0	2.4	2.5	1.9	3.0	3.0	2.8
Height gill slit 2	3.4	4.7	3.8	3.8	2.9	4.0	3.3	2.1	3.7	2.9	6.5	8.2	7.3	7.5	2.6	2.7	2.1	3.2	3.2	3.1
Height gill slit 3	3.3	4.9	4.1	4.1	2.9	4.4	3.5	2.3	3.7	2.9	6.3	8.0	7.2	7.5	2.7	2.9	2.2	3.2	3.4	3.2
Height gill slit 4	2.8	4.6	3.7	3.8	2.6	3.7	3.1	2.0	3.4	2.7	6.4	7.9	7.1	7.4	2.4	2.7	2.1	2.9	3.4	2.8
Height gill slit 5	1.9	3.8	2.7	2.7	1.9	3.0	2.4	1.3	2.7	1.9	6.7	8.1	7.4	6.8	1.7	2.4	1.8	2.0	2.4	2.2
Trunk breadth	12.0	14.6	13.1	-----	11.2	13.1	12.1	9.0	12.1	10.4	10.9	14.4	12.4	16.2	7.1	7.1	7.9	9.0	10.3	12.0
Trunk height	7.8	14.8	12.4	12.1	10.5	12.2	11.4	8.5	12.6	10.6	11.8	15.3	13.7	18.3	10.3	9.2	9.3	11.6	11.4	11.6
Vertical height 1 D	10.0	14.4	12.9	-----	7.5	9.4	8.5	6.2	9.3	7.6	8.6	10.1	9.6	9.8	6.2	7.5	6.6	12.4	12.6	9.0
Base 1 D	10.0	11.3	10.7	9.8	7.6	9.0	8.4	6.5	7.8	7.0	8.2	9.4	8.9	9.4	5.3	6.7	5.2	10.2	9.1	8.6
Vertical height 2 D	2.9	4.2	3.4	-----	1.8	2.5	2.1	2.1	3.1	2.7	.9	2.0	1.4	1.7	.7	.6	.6	2.1	2.3	3.1
Base 2 D	3.0	3.9	3.4	3.0	2.1	2.8	2.4	2.6	3.8	3.5	.8	1.1	1.0	1.4	.6	.8	.6	2.5	2.3	3.6
Vertical height anal	3.3	6.0	4.3	-----	2.3	4.0	3.2	2.5	4.3	3.4	1.0	2.2	1.6	2.0	1.1	1.3	.9	2.9	2.5	3.7
Base anal	3.5	4.7	3.9	4.2	2.8	3.3	3.0	3.1	4.3	3.7	.8	1.4	1.1	1.7	1.0	1.5	.8	3.8	4.0	3.9
Upper margin C	23.4	28.7	27.5	27.9	22.2	27.0	26.0	23.6	26.0	24.5	19.9	22.1	20.7	23.4	51.9	48.9	54.1	26.9	25.8	25.0
Lower margin C	12.5	14.7	14.0	14.1	11.4	13.5	12.6	11.1	14.0	12.2	15.2	17.4	16.2	16.6	7.0	-----	6.6	12.7	12.8	11.6
Pect. ant. edge	21.5	26.1	23.8	18.3?	16.2	20.9	19.3	19.1	23.3	21.3	17.0	25.1	19.6	17.0	17.7	20.1	18.6	14.0	14.1	17.4
Pect. free inner edge	5.1	6.7	5.8	6.6	3.3	4.9	4.4	3.1	4.9	3.9	3.9	5.7	4.5	4.9	1.5	3.0	1.5	2.9	3.1	4.9
Pect. post. edge	19.1	23.4	22.4	17.4?	12.7	18.2	16.7	15.6	20.3	18.6	13.9	22.7	16.8	13.8	17.0	19.7	19.0	11.6	11.7	14.6
Free clasper	2.1	11.2	6.9	-----	2.3	14.2	7.0	2.1	9.6	5.6	2.0	11.2	8.1	4.0	-----	-----	-----	4.6	4.5	-----

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[1] Data from Snyder (1904).

are generally smaller than in their Atlantic counterparts. The gill slit heights of Pacific specimens compare with the Atlantic forms as follows: Pacific great blues, larger; whitetips, smaller; silkies, about the same size.

The other species listed in table 5 either lacked Atlantic counterparts or were represented by an inadequate size range for comparative purposes. The present data for *Alopias pelagicus* are derived from a 354.3-cm. male and 2 females of 166.8 and 349.5 cm., total length. The mean values presented in table 5 agree fairly well with the measurements given by Nakamura (1935) for adult specimens from Taiwan, and where the means do not agree the range in our values (not given here) overlaps Nakamura's figures. Finally, our data for mackerel sharks (*Lamna ditropis*) are based on small specimens (95.8 and 96.1 cm., total length) and do not appear to be comparable to those of the Atlantic mackerel shark (*L. nasus*). For identification purposes it is of interest that our small *ditropis* have a basal lateral denticle on the teeth (as shown by Roedel and Ripley, 1950) but have relatively long snouts. The distance from the snout tip to the anterior edge of the eye is only slightly less than half the distance between the posterior edge of the eye and the first gill slit.

Another identification problem concerns the name to be used for the Pacific whitetip. Our data and those of other authors (Hubbs 1951, Krefft 1954) agree very well with descriptions of the Atlantic whitetip (*Pterolamiops longimanus*) given by Bigelow and Schroeder (1948) and Springer (1950), but there is a possibility that *P. insularum*, which was described from Oahu by Snyder (1904), actually represents the species under discussion. Snyder's measurements of the holotype have been converted to percentage values and listed in table 5 for comparative purposes, but these figures do not solve the problem. The principal differences between *insularum* and other Pacific specimens are in the morphology of the pectoral fin, with this structure being relatively small in *insularum*. This could be caused by either the type being an aberrant specimen, *insularum* being a distinct species, or doubtfully, by much different methods of measurement. It would seem that *longimanus* is the name to be applied to the whitetip reported on here unless future work reveals it to differ from the Atlantic form in some manner not considered at this time.

The length-weight relationships obtaining for the whitetip, silky, bonito, and great blue sharks are shown in figure 20. The data indicate that the whitetip, silky, and bonito sharks have nearly identical weights for any given length, but that the great blue is a lighter fish. In the original plots the data were segregated by sex, and in the

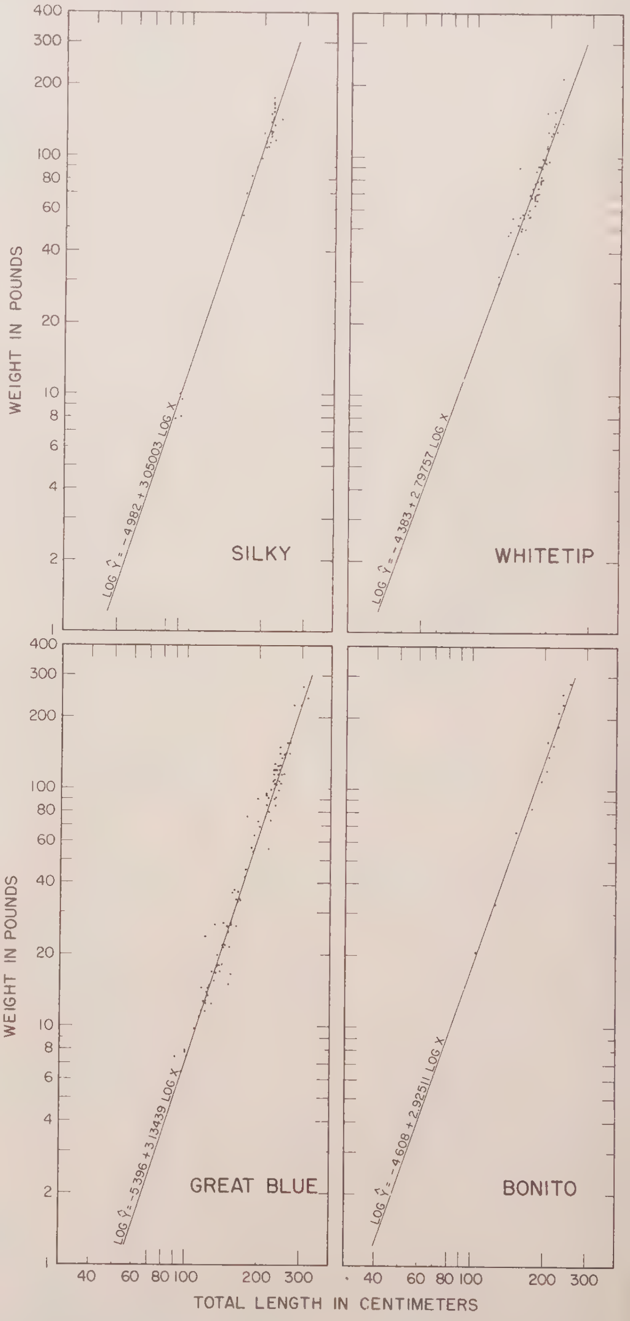

FIGURE 20.—Length-weight relationships for whitetip, silky, bonito, and great blue sharks.

great blue and whitetip sharks females were slightly heavier than males. This is to be expected, for some of the specimens were known to be gravid. The original data were also broken down by locale, but no differences in length-weight of the sharks were noticeable between those from the Line Islands, the Phoenix Islands, various isolated oceanic positions, and the west coast of Central America.

SUMMARY

1. This report is based on the catch records of 34 cruises made in the area between 50° N. and 20° S. latitude and 110° W. and 175° E. longitude during 1952–55. Of 6,118 sharks captured on longline gear, there were 2,512 great blues, 2,176 silkies, 1,187 whitetips, and 243 belonging to 9 relatively uncommon species.

2. The 12 shark species taken show considerable differences in range and abundance. The great blue and the bonito were wide ranging, the former being abundant, the latter uncommon; the whitetip and silky were abundant warm-water forms with the whitetip's range lying roughly between 20° N. and 20° S. latitude and the silky's more narrowly equatorial; the mackerel shark was uncommon and subarctic; the 3 species of thresher sharks were uncommon and equatorial, but may have broader ranges; and the soupfin, hammerhead (2 species), and blacktip were all rare in POFI's catches.

3. The great blue shark appeared to make pronounced northern migrations, probably reproductive in nature, during the warmer parts of the year. Migrations followed the advance and retreat of a transition zone between two major ocean currents. Whitetip and silky sharks were nearly uniformly abundant throughout the year. Their most northerly records were obtained in summer.

4. When the vertical distribution of sharks is analyzed by relative depth of hook-of-capture, the northern great blues are found to be taken principally by shallow hooks and the southern ones by deep hooks. The species apparently favors temperatures between 45° and 69° F. Perhaps also influencing the great blue's vertical distribution in boreal latitudes is the larger amount of food present on the surface. Bonito and thresher sharks were broadly eurythermal, whereas the mackerel appeared to be more nearly stenothermal. The whitetip was surface-dwelling north of the Equator and bathypelagic to the south; the silky shark was uniformly distributed at all hook depths.

5. In the equatorial region the great blue and whitetip sharks were more abundant during warm years than cold, but the silky shark appeared to be the opposite. This difference in abundance may represent a behavioral interaction rather than a temperature-induced phenomenon.

6. In the Equatorial Countercurrent (5° N. to 10° N.) overall shark abundance decreased from east to west between 110° W. and 175° E. longitude, paralleling the situation found for zooplankton volumes. Between 5° N. latitude and the Equator, total shark abundance was minimal at about 140°–150° W. longitude and higher on either side, whereas between the Equator and 10° S. latitude just the reverse occurred. The former situation is similar to that found for inorganic phosphate, the latter similar to that for tuna and zooplankton. The trophic relations obtaining in these situations remain to be demonstrated.

7. The silky and thresher sharks were more abundant near land, whereas the whitetip and great blue were more strictly oceanic, and declined in abundance near islands. There is some evidence for biotic interaction (food competition) between the silky and whitetip sharks in areas intermediate between the neritic and oceanic provinces.

8. All sharks examined were found to subsist principally on small fish and squid, and occasionally to ingest inedible objects. Some species probably capture live tuna on occasion.

9. In northern waters shark damage to hooked tuna averaged only about one percent of the catch, and the abundant shark there, the great blue, is regarded as rather harmless in this respect. In the equatorial area, damage amounted to about 20 percent, and was largely attributed to the silky and whitetip sharks. In this region damage was related to shark abundance only when tuna abundance was low. Shark and tuna abundance themselves were not correlated.

10. Several species of sharks tend to school by sex, and segregation of this type is known as behavioral when caused by size dimorphism between the sexes, or geographical when caused by other factors. The great blue, whitetip, and silky sharks

exhibit sexual segregation to the extent that catches may show a 1 : 1 sex ratio or may consist of solely one sex. For the great blue shark, males comprised an increasingly smaller proportion of the catch to the north, and the mean size of both sexes in mixed catches steadily decreased to the north, with both being about the same length at any latitude. In unisexual catches both sexes were larger than in mixed catches. In individual catches containing both sexes there was a tendency for a few large females to occur with numerous small males or vice versa. On a secular basis it appears that in the winter both sexes occur together in about the same ratio, females begin predominating in the spring, unisexual schools form in the summer and autumn, and reassembly of mixed schools takes place in the winter.

11. Gravid females of the great blue shark measuring from 208 to 247 cm. (total length) were taken throughout the year along with nongravid specimens of the same size range. The largest embryos were found in March and May but no pupping season could be demonstrated. The number of embryos ranged from 4 to about 40, with large pups (34 to 48 cm.) being of the same size as numerous longline-caught specimens. Gravid females of the silky shark, ranging from 213 to 236 cm., were taken throughout the year and were similar in size to nongravid specimens. The number of fetuses per female ranged from 4 to 11.

12. Detailed morphometrics were obtained from 16 whitetip, 12 silky, 22 great blue, 13 bonito, 2 mackerel, 5 thresher, 2 hammerhead, and 2 blacktip sharks. Pacific whitetip, silky, and great blue sharks differed from their Atlantic counterparts in having a greater distance between the snout and all fins except the anal, and also in having smaller anal, second dorsal, and upper caudal fins. Minor differences are shown for other characters, but none of these indicates a lack of conspecificity between the two oceans. The whitetip reported on is termed *Pterolamiops longimanus* on the basis of marked differences between it and the Hawaiian *P. insularum.*

13. Whitetip, silky, and bonito sharks have nearly identical length-weight relationships but the great blue is a lighter, more slender fish. No geographical differences were noted in length-weight.

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STABILIZING HETEROPOLY COLOR IN THE ESTIMATION OF PHOSPHATE-PHOSPHORUS IN SEA WATER

Instability of the reduced phospho-molybdenum-complex color has long been a source of difficulty and inconvenience in the estimation of phosphate-phosphorus in sea water. Complete color development requires approximately 10 minutes for the standard method and remains relatively constant for only 20 to 30 minutes.

The chief source of difficulty with the so-called "molybdenum blue" method appears to be inherent in the nature of the reductant. The author has developed a modification of the standard method using a supplementary reductant, hydrazine sulfate, which gives a reduction product of extreme stability as compared to other methods previously described in the field of marine chemistry. Color in the conventional method is stable for approximately 20 minutes for the low phosphate concentrations, as compared with 5 days with the hydrazine sulfate modification.

In the course of investigations evaluating the new method, sources of error other than instability were examined and efforts made to overcome them. For example, standard computations for the analysis are based on the assumption that optical properties vary in accordance with Beer's Law. Such an assumption is not valid in the concentration ranges below 1.0 microgram atom per liter and above 4 microgram atoms per liter, and is only approximately true in the intermediate ranges. The use of graphical methods eliminates this source of error.

The nature of the "salt effect" error is also considered and evidence is introduced which supports a new concept of the mechanism of "salt effect." This evidence would seem to indicate that salt error may not be due to actual color differences in the presence of certain ions, but rather to a turbidity phenomenon resulting from the absence of key ions.

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